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IDENTIFICATION OF THE ENERGY PARAMETERS OF AN ELECTROHYDROIMPULSE PLANT FOR THE PRODUCTION OF VALUABLE COMPONENTS FROM ORGANIC RAW MATERIALS

Gulnaz Kartbayeva
Candidate of Biological Sciences, Associate Professor
Department of Zoology**
Moldir Duisenbayeva
Corresponding author
Doctoral Student*
E-mail: m_o_l_d_i_r_89@mail.ru
Bekbolat Nussupbekov
Candidate of Technical Sciences, Professor*
Elmira Mussenova
Candidate of Physical and Mathematical Sciences, Professor
Department of Physics and Nanotechnology**
Zhanaidar Smagulov
Candidate of Physical and Mathematical Sciences, Associate Professor
Department of Radiophysics and Electronics**
Alikhan Kurmanaliev
Master's Student*
*Department of Engineering Thermophysics named after prof. Zh. S. Akylbayev**
**Karaganda Buketov University
University str., 28, Karaganda, Republic of Kazakhstan, 100024

The paper presents the results of experimental studies on the developed bone degreasing stand. The object of the study is the production of valuable components from organic raw materials.

Fractions of cattle crushed to the size of 2.5 mm, 5.2 mm and 10.5 mm were used to identify the effective mode of operation of an electrohydroimpulse installation.

Physical and chemical methods of fat extraction are currently not relevant from the point of view of economy, due to environmental damage and labor intensity. In this regard, new effective methods of extracting fat from bone mass are needed. Therefore, the proposed method of extracting fat by spark discharge is an actual and alternative method for today.

During the study, an acceptable temperature regime for fat production was obtained. Next, a laboratory stand was assembled, with which you can degrease the bone mass without changing the properties of fat.

Experimental studies show that with an increase in the capacity of the capacitor bank in energy storage devices and the length of the discharge gap, the bone degreasing process becomes more efficient. During the study, it was found that at a liquid temperature of 38 °C and a pulse voltage of 25 kV on a switching device of an electrohydroimpulse installation, the degree of fat extraction increases without destroying the morphological structure of bone mass.

Using the hexane extraction reaction, we determined the efficiency of fat extraction at a temperature of 38 °C, at which the fat mass from the bones is effectively broken down, and using the UV-1800 spectrophotometer, we determined the amount of protein in the bones before and after treatment.

The study also showed that with a capacitor bank capacity of 0.5 uF, crushed to a fraction of 10.5 mm of pelvic bone, the separated fat is 18.7 %, and with constant grinding of the capacitor bank to a fraction of 2.5 mm – 19.4 %

Keywords: organic waste, bone mass, temperature, bone, spark discharge, energy parameters, secondary resource, recycling

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1. Introduction

The study of the extraction of valuable components from organic waste using an electrohydroimpulse installation is relevant in the field of meat and food industry. Thus, with a pulsed electric discharge in the liquid, the effective destruction of the bone matrix in which the fat mass is retained occurs. This principle can be used to extract valuable components from various materials, as well as improve the quality of the product and use it for processing water-containing foods.

Today, the processing of secondary resources of the meat industry has several important aspects, both economic and social, not only for the enterprises of the industry, but also for the country as a whole.

Fat extraction is the most important stage of the technological process of animal fat production. Therefore, there are various technological methods that allow you to act on adipose tissues in such a way as to separate the fat contained in them from fat cells. The mild steaming mode is due to the need to preserve the mechanical strength of the tubular bone as a decorative material. In addition, high temperature and prolonged contact of fat with heated bone lead to deterioration of the organoleptic characteristics of the final product. In this regard, it is relevant to study ways to obtain valuable components from organic waste and solve constructive problems.

2. Literature review and problem statement

Currently, much attention is being paid to the agricultural sector, including animal husbandry. Therefore, there is a rapid increase in waste when obtaining the necessary products for sale. The paper [1] discusses technological equipment for the thermal processing of agricultural raw materials. But the work does not describe the ways of introduction into production.

In [2], a pulsed electric field is used for food preservation, in which short electrical pulses are used. But it is suitable for preserving liquid and semi-liquid products, removing harmful microorganisms and obtaining functional components. The main purpose of pretreatment is to inactivate the microorganisms present, while minimizing changes in physical, sensory and nutritional properties. It is also necessary to consider using the method for solid waste.

The paper [3] examines the policy in the field of functional food products, expressed in food intended for medical use, and also develops and defeats the food industry to produce a variety of new food products. Special attention is paid to the study of antioxidant and anti-carcinogenic food additives, as well as pre- and probiotics. This review presents the latest trends in science and industry in this area. The ways of obtaining food products are written in great detail.

Experimental data are needed that show the scientific relationship between the components of food and its health benefits.

In [4], the potential of pineapple fruit and pineapple waste was investigated to be used as raw materials for poultry supplements based on their enzyme activities. During this study, it was found that pineapple fruits and pineapple waste contain digestive enzymes such as xylanase, protease and cellulase, which can be used as additives for poultry. This work is very relevant in the field of poultry farming. In the future, the use of pineapple waste in other industries should also be considered.

In [5], the effect of MEF treatment on permeability was studied. The effects of the frequency and intensity of the electric field were investigated. The cell structure was studied by transmission electron microscopy (TEM). The effectiveness of the method depends on various factors such as time, temperature, field strength, frequency, sample selection and preparation, and is effective even at lower field strength.

In [6], the effects of the frequency and intensity of the electric field were investigated. The cell structure was studied by transmission electron microscopy. The paper does not describe a complete analysis of these studies.

The work [7] demonstrates the use of PEF technology, which can improve the functionality, extractability and extraction of nutrients, as well as the bioavailability of trace elements and components in various food products. But the technologies of implementation in production were not described.

In [8], the effect of pulsed electric field (PEMF) treatment of various intensities on the electroporation of the cytoplasmic membrane of Chlorella vulgaris and on the extraction of carotenoids and chlorophylls was investigated. The disadvantage is that at a lower electric field strength (10 kV·cm^{-1}), cells undergoing reversible electroporation were observed even after 50 pulses lasting 3 microseconds.

An exponential increase in either of these parameters would degrade the quality of the testing medium. For instance, the paper [9], reported an increase in the yield of valuable compounds in grape seeds and borage leaves at a lower temperature and shorter extraction time than in control samples. This study also found significant differences between the treated and control samples. The paper considers all effective technical parameters of a pulsed electric field to improve the aqueous extraction of polyphenols and non-oxidant compounds. Therefore, the results of the study are relevant today in the field of waste recycling.

The work [10] presents the modeling and optimization of the extraction process of polyphenols from borage leaves using the reactive surface method (RSM) and the use of this extract for the preparation of emulsions. But the content of p-anisidine in the control and the emulsion with 3 % extract was reduced to 73.6 %, and in the emulsion with BSA – to 86.3 %. At other concentrations, similar behavior was observed. The paper did not consider the use of this method for other plants.

In [11], an ultrasound-assisted extraction (UAE) procedure was developed using selected deeply eutectic solvents (DES) as a solvent to simultaneously optimize the total phenol/flavonoid content (TPC/TFC). The composition of the solvent has not been fully considered.

In [12], the effect of pulsed electric field (PEF) treatment of various intensities on the electroporation of the cytoplasmic membrane of Chlorella vulgaris and on the extraction of carotenoids and chlorophylls was investigated. However, currently there are still a number of obstacles to fully exploiting the benefits of microalgae producing biological products, such as the ability to successfully extract these compounds from cell biomass. The work is very relevant in the chemical industry.

The paper [13] considers the effect of pulsed electric fields on the structure of organic raw materials. It was found that pulsed electric fields with an amplitude of several kilovolts per centimeter and a duration of a submicrosecond prevent the growth of species harmful to aquatic organisms on the surface. PEF is a pretreatment that contributes to an increase in water loss during overdose with limited absorption of solutes, which leads to a minimal change in the taste of the product. It was shown that the field strength is one of the factors having a significant impact on mass transmission, while the effect of increasing the number of pulses was not so noticeable.

The effect of dehydration of fruits and vegetables is considered in [14]. The authors proposed a pulsed electric field, the most promising method of non-thermal processing, which affects the permeability of membranes in a very short time, practically does not change the product matrix and has a positive effect on mass transfer during subsequent processing of food products. The results of the work are important in the field of food waste processing. As part of the study, all effective methods and techniques of processing food waste were considered.

Currently, the separation of valuable components from organic waste using an electrohydroimpulse method is not widespread. We believe that this is due to insufficient knowledge about this method and insufficient information. The presented data allow us to take a fresh look at the technological role of an electrohydroimpulse installation, now it is not only an effective way to obtain valuable components, but also a fairly inexpensive and waste-free production at that time. The use of a high pulsed shock wave generated by spark radiation in a liquid makes it possible to easily and environmentally isolate fat from bone mass. Therefore, the search for constructive solutions to improve the methods of obtaining valuable components from organic waste and its economical consumption is promising.

3. The aim and objectives of the study

The aim of this work is to identify the influence of the electrohydraulic effect and fluid temperature on bone mass degreasing.

To achieve this aim, the following objectives are accomplished:

– to determine the effect of mass temperature on the degreasing of organic materials;

– to determine the voltage, interelectrode gap and power of the electrohydroimpulse installation for targeted extraction of fat from the matrix.

4. Materials and methods

The object of the study is the production of valuable components from organic raw materials. The main hypothesis of the study is that a high pulsed shock wave, which generates spark radiation in a liquid, destroys the structure of the bone matrix. With constant heating of the liquid and at the same time the impact of shock waves arising from high-voltage pulses entering the electrode, high pressure and a cavitation cavity are formed in the container where the bone mass is located. When the first shock waves form in the liquid, microcracks form in the outer part of the bone mass. With further processing of bone mass by spark discharges, the bone structure, which contains fat mass, is completely destroyed. And constant heating makes it possible to additionally warm up the mixture, which makes it possible to gradually separate the fat mass from the bone cells, and the resulting shock wave completely removes fat from the bone mass.

As we assume, an assembled laboratory installation using a microburst, accompanied by the rapid release of a large amount of energy, is an attractive and promising area for processing organic raw materials.

The technological solution is achieved due to the fact that the electrohydroimpulse method of obtaining valuable components from crushed bone is produced with constant heating of the bone mass.

Since the fat in the tubular bone is mainly contained in the composition of the bone marrow, the bone is either sawed or sawed lengthwise to open the internal cavity. After loading, the bone is filled with water so that it is completely in the water. The method of sample preparation is described in [15].

For laboratory work, we used cattle bones. For laboratory work, bones were crushed to fractions of 2.5 mm, 5.2 mm and 10.5 mm. Next, the crushed bone mass was weighed and soaked in water for 12 hours. After the time had elapsed, the bone mass soaked in water was weighed to determine the exact mass.

A laboratory model was assembled to determine the temperature parameters. The assembled laboratory model is shown in Fig. 1.

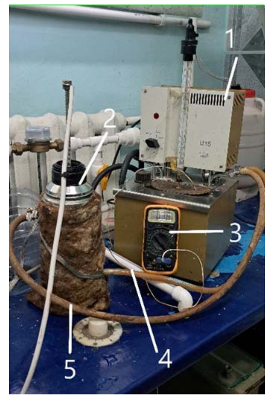

Fig. 1. Laboratory model for setting the temperature regime for melting fat from bone mass: 1 – thermostat 1; 2 – liquid heating tank; 3 – multimeter; 4 – water outlet tube; 5 – water supply tube

Water heated to the desired temperature by thermostat 1 using a tube 4 is fed into a container 2 with bone and water, water from the thermostat heats the outer part of the vessel. The container was covered with felt to maintain the temperature. The cooled water through the tube 5 re-enters the thermostat, heats up and is fed back. With the help of a multimeter, the temperature in the container is constantly recorded. Fig. 2 shows the general scheme of the working capacity [16, 17].

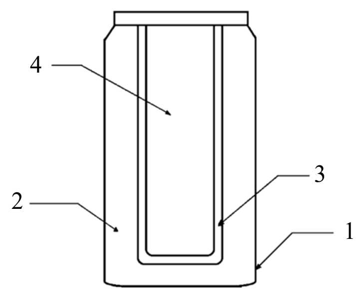

Fig. 2. Working capacity for heating bone mass: 1 – outer wall; 2 – vacuum; 3 – mirror coating inner wall; 4 – liquid volume

Heated water from the thermostat via a tube enters the vacuum part of the working container indicated in Fig. 2. As can be seen from Fig. 2, water is supplied from the top of the container, covering the entire surface. For further heating, the cooled water enters the thermostat through a tube.

After heating, the bone mass is weighed again on an electronic scale. Due to weight loss, the mass of fat separation from the bone is calculated. Based on the results obtained, graphs are constructed and an analysis is carried out.

The obtained samples were sent for further research to the laboratory of engineering profile "Physico-chemical research methods" at the Y. A. Buketov Karaganda University. To determine the remaining amount of fat in the samples, the bones were soaked in hexane extraction in an amount of 6 ml during the day.

As you know, in addition to fat, there is protein in the bone. It is the basis in the production of gelatin. In addition, protein is very important in the preparation of animal feed meal, as it is enriched with minerals. We also examined the amount of protein after preheating the bone mass. A two-beam scanning spectrophotometer UV-1800 was used for this purpose. The general view of the equipment is shown in Fig. 3.

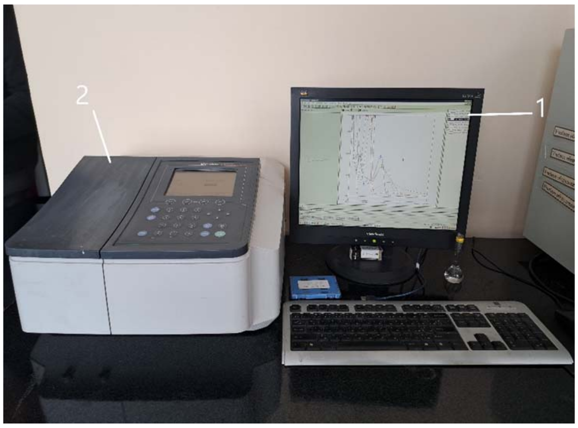

Fig. 3. Two-beam scanning spectrophotometer:
1 — computer; 2 — spectrophotometer

The obtained images were extracted with a 100 ml sodium chloride solution, with an orbital shaker, shaking speed 150 rpm, for 24 hours at room temsperature 25 °C. After that, the extract was filtered, if the solution was cloudy, a centrifuge was used, at 3,500 rpm for 5 minutes.

We have assembled an experimental electrohydroimpulse unit and a crushing unit that allows us to grind and extract fat from bone mass using an underwater spark discharge. A general view of the experimental electrohydroimpulse bone degreasing plant is shown in Fig. 4.

The maximum voltage on the air arrester 2 reaches 35 kV. The voltage was measured using a mirrored kilovoltmeter. For experimental work, the voltage varied from 15 kV to 25 kV.

When shock waves occur in an aqueous medium, under the action of pulses with a frequency of 7–15 Hz, water penetrates into the bone, destroying the bone structure, and therefore the transition of fat mass into solution occurs. We determined the frequency range using experimental studies [18, 19].

Fig. 4. Electrohydroimpulse installation for degreasing bone mass: 1 — experimental electrohydroimpulse installation consists of a control panel; 2 — generator with an air arrester; 3 — capacitor with a protection system

5. Results of the study of the influence of the electrohydraulic effect and the temperature of the liquid on the degreasing of bone mass

5. 1. Results of the study to determine the effect of mass temperature on the degreasing of organic materials

Studies have shown that with an increase in temperature, there is an intense release of fat from the bone. The experiment was carried out several times at temperatures from 32 °C to 38 °C. The pelvic bone of cattle was taken for research. The effect of the temperature regime on the degreasing of bovine bone mass is shown in the form of a graph in Fig. 5.

The study showed that the intensity of fat separation from bone mass was positive in the 3rd sample. Based on tabular data, we know that the intensity of fat release from the pelvic bone is 22 %. Our study showed that in the 1st sample, fat excretion was 10 % of the total fat in the bone mass. And in the 2nd and 3rd samples, we can observe the release of fat in the range of 15–17 %. In the 4th sample, the total fat breakdown rate is less than 10 %. Fig. 6 shows a graph of fat breakdown.

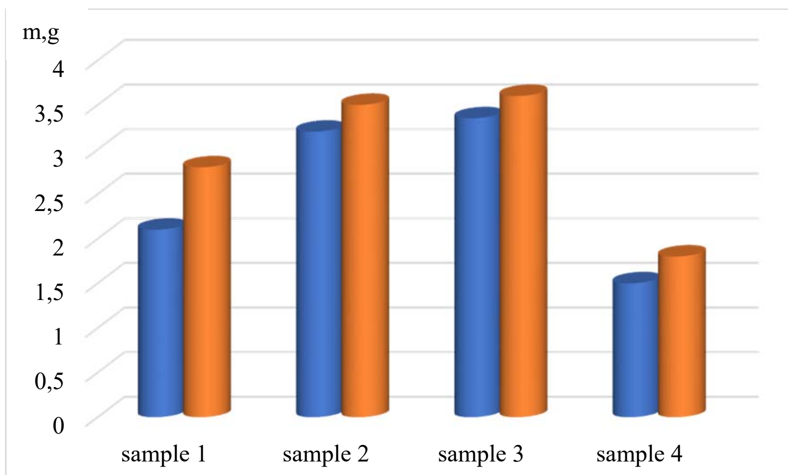

Fig. 5. Effect of temperature conditions on the degreasing of bovine bone mass

As you can see from the graph, the fat content in the bone before heating was 8.19 %. After laboratory studies, the residue of bone fat was determined using hexane extraction, which amounted to 4.77 % in the 1st sample, that is, almost half of the fat was removed, and the smallest 2.84 % in the sample. And in the 2nd sample, the highest fat excretion is 5.93 %.

The protein content in the bone mass was also studied using a two-beam scanning spectrophotometer UV-1800. The results of the experiment are shown in Fig. 7.

On the graph, the line marked in green is the concentration of protein in the bone before processing. And the lines located close to each other show the amount of protein in the bone after heating. As we can see in the graph, the protein before bone processing at an absorption of 370 nm has a value of 2.0000 Abs. After processing, we see that the absorption value decreased at an increase of 380 nm in the range of 1.4000–1.6000 Abs.

After preheating, the bulk of the fat remains in the sample. For deep extraction of fat from bone mass, it is necessary to destroy the protein structure that holds fat. We used an electrohydroimpulse method, which makes it possible to obtain the desired product without destroying the basic properties and composition.

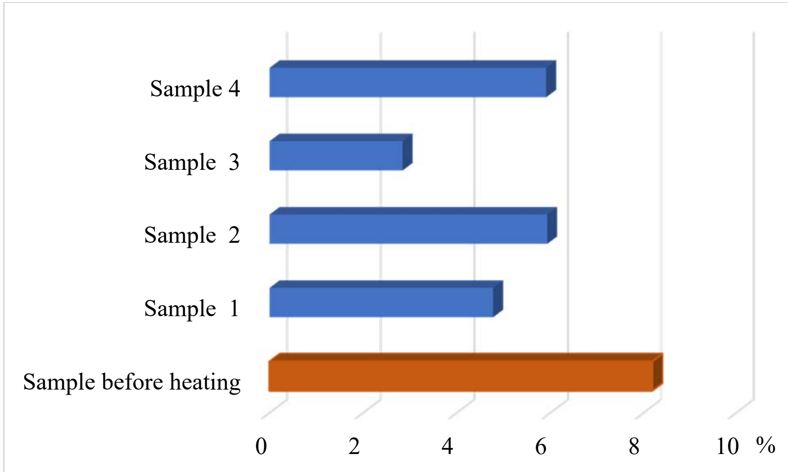

Fig. 6. Fat release from the bone matrix during heating

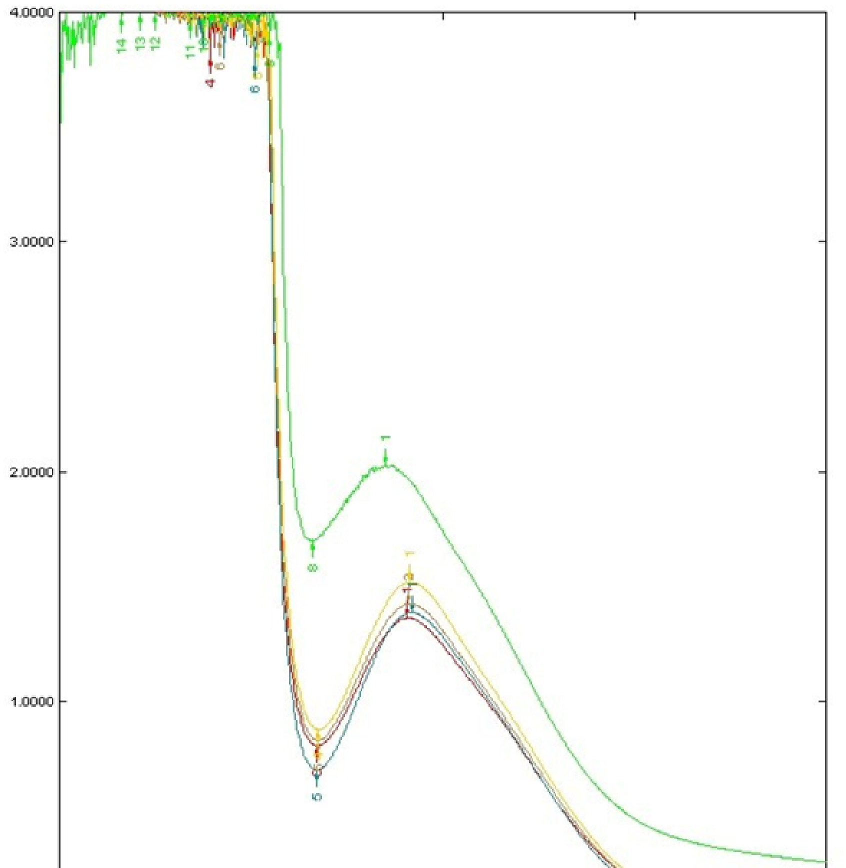

Fig. 7. Indicator of the protein content in the bone composition

5. 2. Results of determining the voltage, interelectrode gap and power of an electrohydroimpulse installation for targeted extraction of fat from the matrix

After receiving party of the bone fat, then using an electrohydroimpulse unit, the bone mass was processed for additional extraction.

Fig. 8 shows the effect of the capacitor bank capacity of the bone fat removal unit at U=15 kV, l_p=7 mm, $t_{mixture}$=32 °C.

During the study, the voltage was 15 kV, the capacity on the switching device was 0.5 uF, and the temperature of the water was increased to 32 °C. As you can see on the graph, when grinding the bone to a fraction of 10.5 mm, the fat separated from the pelvic bone was 18.2 %, and during grinding to a fraction of 5.2 mm it was 18.5 %.

Fig. 9 shows a graph of the effect of the capacitance of the capacitor bank of the crushed bone degreasing unit at U=25 kV, l_p=9 mm, $t_{mixture}$=38 °C.

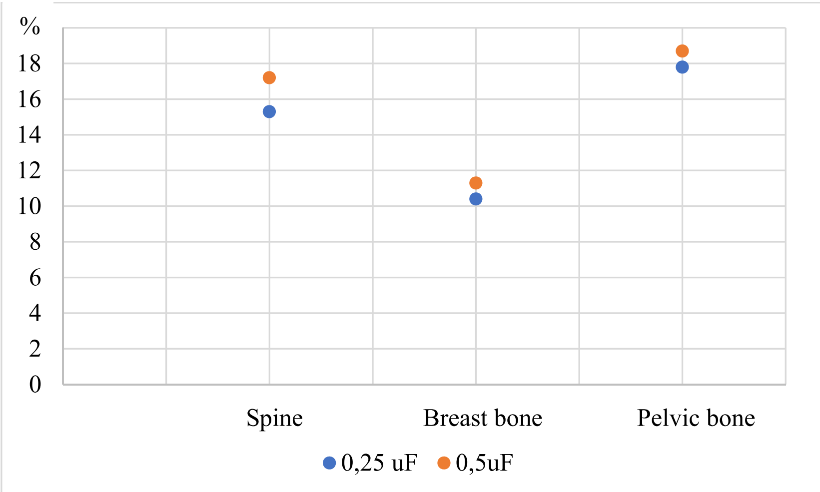

Fig. 8. Graph of the effect of the capacitor bank capacity of the installation depending on the type of bone at U=15 kV, l_p=7 mm, $t_{mixture}$=32 ℃

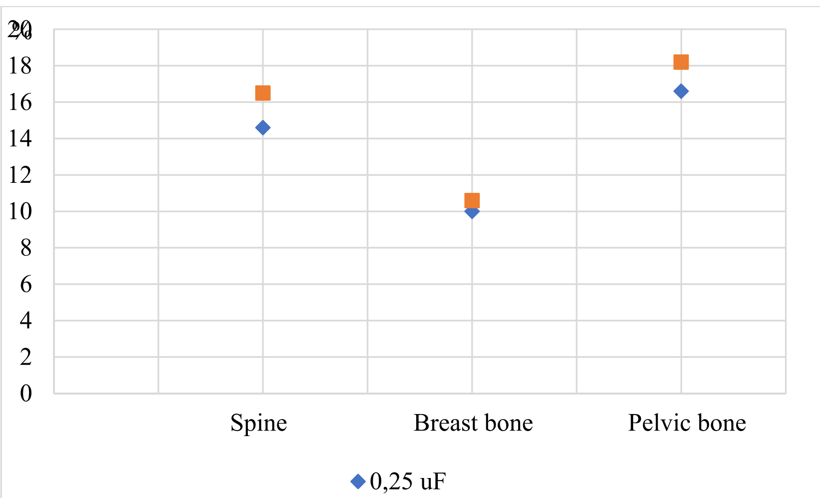

Fig. 9. Graph of the effect of the capacitance of the capacitor bank of the crushed bone degreasing unit at U=25 kV, l_p=9 mm, $t_{mixture}$=38 °C

During the study, the voltage was 25 kV, the temperature of the mixture was increased to 38 °C. As you can see on the graph, with a battery capacity of 0.5 uF and bone crushing to a fraction of 10.5 mm, the separated fat of the pelvic bone was 18.7 %, and during grinding to a fraction of 2.5 mm it was 19.4 %.

If we compare the two graphs, we see that with increasing voltages and capacitance of capacitor banks, fat extraction increases.

6. Discussion of the results obtained in the study of the influence of the electrohydraulic effect and the temperature of the liquid on the degreasing of bone mass

To preserve the composition and properties of the extracted valuable component, it is necessary to work at lower temperatures. This fact is consistent with the figures, which illustrate that at a temperature of 38 °C, it is possible to degrease bone mass up to 18 %.

In the study [20], the process of extracting fat from organic compounds was presented and a working cell was assembled. The methodology and conditions for conducting research and the procedure for conducting tests have been developed. The acceptable temperature of the mixture was chosen in the range of 32–50 °C to extract a valuable component from the bone mass – fat. It was found that at temperatures below 32 °C, some of the fat is retained by the skin. As a result of adsorption and capillarity, the viscosity and fat content on the surface are reduced, as well as the extraction process time is shortened. Therefore, our work provides for constant heating of the working tank, which is shown in Fig. 2. This makes it possible to reduce the temperature to destroy the bone structure. Further, in order to fully obtain a valuable component, a technology that destroys the bone structure is needed.

The use of a powerful pulsed shock wave generated by spark radiation in a liquid makes it possible to easily and environmentally extract valuable components from bone mass. This fact is consistent with Fig. 8, 9, which illustrates that with an increase in the length of the discharge gap and the capacity of the capacitor bank in the energy storage, the output of fat from bone mass increases. It follows from this that the effective isolation of valuable components from the material requires a large number of shock waves that destroy the structure of the bone in which the fat mass is enclosed. Also, constant heating of the working tank provides effective extraction of fat from the bone matrix, as there is a splitting and intensive release of fat.

It was found that the impulses generated by an electric discharge have sufficient force to destroy fat cells.

The application of the proposed method makes it possible to effectively degrease the bone of cattle, thereby ensuring waste-free production in the agro-industries. The skimmed bones obtained by the proposed method are used as raw materials for handicrafts, as well as for the production of gelatin, glue and bark flour.

Nowadays, it is often possible to face the fact that industrial organizations are reluctant to agree to purchase new developments with which environmental and economic benefits can be achieved. It is also difficult to purchase pulse capacitors, which are manufactured by mailboxes.

7. Conclusions

1. The study showed that at a temperature of 38 °C, the greatest release of fat from the bone matrix occurs, and it is also necessary to maintain a constant temperature of the mixture for complete degreasing of the bone mass.

After processing the data, it was found that the 3rd sample had the highest fat release, it was 17 % at a temperature of 38 °C. As can be seen from the graph, the fat content in the bone before warming up was 8.19 %. After laboratory studies using hexane extraction, the remaining bone fat was determined, and it was found that in the 2nd sample the highest fat excretion was 5.93 %. An analysis was also performed to determine the amount of protein in the bone. As the result showed, effective protein release occurs during the study. The results of the study showed that in the sample before processing at an absorption of 370 nm, the absorption is 2.0000 Abs., and in the bones after processing at an absorption of 380 nm, the absorption is 1.6000 Abs.

2. After establishing the acceptable temperature, for complete degreasing of the bone, the optimal parameters of the electrohydroimpulse installation were investigated. As can be seen from the graph, it was found that with an increase in the length of the discharge gap to l_p=9 mm, the capacitance of the capacitor bank to 0.5 uF in the energy storage, the output of fat from bone mass increases. When the battery capacity was 0.5 uF and the bone was crushed to a fraction of 10.5 mm, the separated fat of the pelvic bone was 18.7 %, and when crushed to a fraction of 2.5 mm – 19.4 %. Using a laboratory model, 10 % to 20 % of the bone fat of the pelvic bone of cattle was obtained.

Conflict of interest

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.

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Data availability

Data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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