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Study of the effect of ultrasonic field in purifying sunflower oil

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Abstract

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An analysis has been made of existing studies in which liquid food products are processed by ultrasonic waves. It was established experimental setup with an ultrasonic generator for the purification of sunflower oil under the effect of the ultrasonic field. A methodology has been developed to determine the optimal frequency of ultrasound, the ultrasound emission power and the time of purification of vegetable oils. The technological parameters of the process of purifying sunflower oil by ultrasonic treatment were determined and experimental process studies were carried out. A basis of experimental data has been developed in the studies of the sunflower oil purification process. In this study the main focus is to determine the technological parameters of the ultrasonic treatment of the raw materials by conducting experimental modeling of the process of cleaning sunflower oil under the action of the ultrasonic field.

*Keywords***:** ultrasonic field; sunflower oil; sediment; magnetostrictive emitter; intensification; cleaning process

Introduction

Sunflower oil is obtained from heated, finely ground sunflower seeds by pressing or extraction. Due to its composition, vegetable oils are physiologically active substances and their nutritional value is determined by the content of polyunsaturated fatty acids needed by the human body to build cells (Van Duijn, 2013; O'Brian, 2007).

Factors that affect the quality of vegetable oils are: raw materials and production technology. The quality indicators of these oils are closely related to the extent of their purification.

In assessing the quality of vegetable oil by physics-chemical performance, the most important are: the colour number, the acid number, the mass fraction of moisture and volatile matter, and the mass fraction of phosphorus-containing substances (Hamm et al., 2013).

Organoleptic indicators are of great importance in determining the type of vegetable oils and their raw material. Physical parameters are important when identifying vegetable oils and they determine the refractive index, viscosity and pour point.

The oil is discarded when there are inappropriate physico-chemical parameters or contains pesticides, heavy metals, mycotoxins in excess of the allowable quantities.

The main indicators that determine the quality of the sunflower oil obtained have direct dependence on the cleaning process. Therefore, the better the oil is, the better this process is (Harutyunyan et al., 2004; Khmelev, 2010).

Introduction

In their studies (Santos et al., 2011; Time & Rabenjafimanantsoa, 2011; Shestakova et al., 2017), they use an efficient technology to purify the phosphate concentrate of vegetable oil by magnetic-acoustic method. It has been shown that ultrasonic field processing and pulsating magnetic field provide a high-quality lecithin-containing product. Thus, the authors prove that the positive effect of the ultrasonic field on phosphorus-containing substances does indeed exist. But this work does not reflect its effect on other related substances. The reason for this may be a narrow range of research and this strand.

In their studies (Abbasi et al., 2016, Su et al., 2013; Abedi et al., 2015, Asgari et al., 2017), they have studied the possibilities of bleaching olive oil and sunflower oil by conventional and ultrasonic methods. The qualitative and quantitative characteristics of bleached oils are compared. The ultrasonic bath used was set at two temperature levels. A series of tests was performed, after which the values of chlorophylls, carotenoids, color range, peroxide value, acidity measurement and free fatty acid were determined. In conventional bleaching, there is a significant reduction in the content of chlorophyll and carotenoids in olive and sunflower oils, while better removal of pigments occurs after ultrasonic treatment. It was concluded that the ultrasonic bleaching process could be considered as an alternative to the usual bleaching method as it may reduce the bleaching process time and temperature. Ultrasonic waves can improve the bleaching process without any harmful effects on fatty acids. However, the bleaching of oils is at the end of the refining process diagram. It consists of a series of physical and chemical operations, and this, of course, involves additional costs.

In his work (Mahmood-Fashandi et al., 2017) he investigated the use of ultrasonic waves in combination with phosphoric acid to reduce the temperature and duration of the process of defragmentation. The results obtained are compared with the conventional methods. Thus, raw soybean and sunflower oil were digested in the presence of acid in an ultrasonic bath. Certain qualitative factors have been identified, such as phosphorus content, peroxide value, acidity, oxidation resistance and fatty acid composition. According to the data obtained, using ultrasonic waves, the required temperature and process time are reduced. In addition, this method does not significantly affect the fatty acid compositions of the oils and can be used as an alternative method for degreasing vegetable oils.

In the studies (Ustenko & Yushkov, 2012; Shmyrkov et al., 2013; Gordon et al., 2009), laboratory and industrial test results were obtained using a waveguide generator. Hydrated soybean oil can be quickly hydrated using ultrasonic acoustic treatment in the presence of a small amount of hydrating reagent. These experiments were performed on ultrasonic waves during the hydration process to separate the phospholipids. And this means that the oil has already been subjected to mechanical cleaning, i.e. there are additional operations. In addition, the above scientific papers use different scientific reagents that have a chemical effect on the oil. All this leads to additional costs for materials and energy.

One possibility for eliminating these negative factors is the use of ultrasonic treatment in the initial purification of vegetable oils, namely during filtration. This method is used in the work (Bredikhin et al., 2017), but the experiments are carried out in a static state using inertial forces in the filtration of the oil. This results in a slower process run, thus increasing the filtering time. All this suggests that it is advisable to carry out sunflower oil purification experiments by filtration using dynamic ultrasound vibrations. It is done when the oil passes through the pressure filter element. Using these experiments, the parameters of the ultrasonic field can be determined, and the cleaning process will be improved.

Materials and Methods

The purpose and objectives of the study

The goal of the study is to determine the technological parameters of the ultrasonic treatment of the raw materials by conducting experimental modeling of the process of cleaning sunflower oil under the action of the ultrasonic field. This will allow the process of cleaning sunflower oil to be enhanced and a high quality product to be obtained.

The following tasks were set to achieve the goal:

– creation of an experimental installation with an ultrasonic generator;

– developing a methodology for determining the effective ultrasound bandwidth, the ultrasound emission power and the time of purification of vegetable oils;

– conducting experimental research on the process of purifying sunflower oil and creating a basis for experimental data.

Experimental setup for filtering sunflower oil using ultrasonic waves

An established experimental installation for cleaning oil with ultrasonic field is presented in Figure 1.

As a working element for forming ultrasound it uses magnetostrictive transducer. This arrangement involves the use of suitable pressure filtration equipment. Based on the

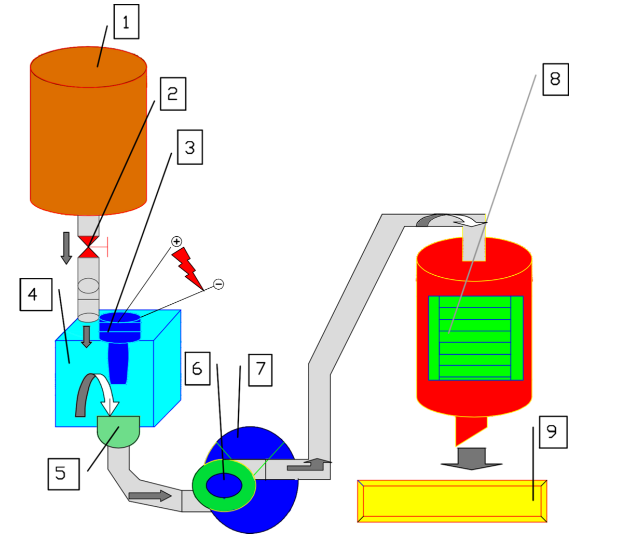

Fig. 1. Experimental installation for cleaning sunflower oil with ultrasonic field:
***1* – tank, *2* – valve, *3* – ultrasonic radiator, *4* – cavitation chamber, *5* – ultrasonic mirror, *6* – pump, *7* – electric motor, *8* – filter, *9* – tank for purified oil**

analysis of literature sources, sunflower oil purification experiments by filtration were performed using ultrasonic vibrations in a dynamic state (Osadchuk, 2010, 2017; Osadchuk & Dudarev, 2018).

An experimental set consists of a primary reservoir with a valve that is connected to a "cavitation chamber" conduit. It has a feed inlet for raw materials and an ultrasonic emitter in the middle. The so-called "ultrasound mirror" is located at the bottom. The "cavitation chamber" is connected via a pipeline to a gear pump that is driven by a rigid electric motor clutch. The pump is connected via a pipeline to the filter, which in turn is connected to the finished product tank.

Technical characteristics of the device

• The device can operate in heated rooms at temperatures ranging from 5 to 60°C and humidity 80%.

• The nominal capacity of the device is 2100 cm^3/hour.

• The nominal speed of the oil is 0.2 m/s.

• The maximum power in the vibrator – 1.4 kW.

• Maximum current equipment (effective) – 28 A.

• Maximum power consumption 500 watts.

• Dimensions: length – 600 mm, height 700 mm.

• Weight no more than – 15 kg.

The method of experimental determination of the parameters of ultrasonic waves

The main tank is filled with unfiltered sunflower oil. A pre-weighed filter element is inserted into the filter. The ultrasonic generator is set to the required frequency. The timer is set at the right time. The oscilloscope is included to measure the voltage that is connected to the generator. After opening the valve, the oil enters the cavitation chamber. The ultrasonic generator is switched on and the oil is processed by ultrasonic vibrations for a specified time. "Ultrasound Mirror" reflects and directs ultrasound waves to increase efficiency. Then the generator is switched off and the electric motor is switched on.

The gear pump pumps sunflower oil and it is filtered under a pressure <0.2 MPa. The oil then falls into the tank and the filter is disassembled and the filter element is weighed. The pump is driven by an electric motor. The electric motor operates at a certain frequency and is controlled by pressing a button. The filter is designed for multiple use with a removable filter element. The sound is output at a frequency of 24 kHz and the power in the vibrator itself is about 900 watts.

The vibrator, which is submerged in oil, excites the ultrasonic vibrations that lead to liquefaction and fluid pressing. The microbubbles are combined in stable embryos, which can then be separated from the base mass (filtered). The occurrence of "fog" and the appearance of a characteristic pressing, the level of which increases with the increase in power, can be observed.

The intensity of the acoustic field depends on its original state. If the system is in a state close to thermodynamic instability (met stability state), the external effects, even with low intensity, can bring it to a qualitatively new state.

The system enters a state of instability when the value of any characteristic parameter (pressure, temperature) is close to critical.

This regime contributes to the destruction of impurities from macromolecules, pollutants and living organisms.

During each experiment the following indicators were taken:

– Indications for oscilloscope:

a) measurement of the voltage of the output terminals of the generator (vibrator voltage);

b) voltage measurements of the generator's extra terminals. They have a resistor with a resistance of 0.05 ohms. And knowing the tension and the resistance, according to Om's law, we get the power of the current (the vibrator current);

c) measurements of the length of the period (frequency of ultrasound).

– the pressure gauge readings on the gear pump outlet;

– indications of the size of the capacitor load;

– output yield measurements of the final product;

– measurement of ultrasonic treatment time;

– measurements of electronic scales before and after filtering.

The experiments were carried out by changing the following indicators:

– Frequency of ultrasonic vibrations 24-130 KHz;

– Vibrator power 130-1400 W;

– Ultrasonic processing time 30-600 s;

– Changing the type of oil;

– Types of vibrators: flat, round – different diameters, of the rotating shaft (from 8 to 10 mm).

The experiments were conducted in a warm room with good lighting and ventilation.

Results

During the experimental studies of the effects of ultrasound on the oil purification process, we identified:

– the temperature of the oil filtration at the frequency change of the radiant fan oscillation, as shown in Figure 2.

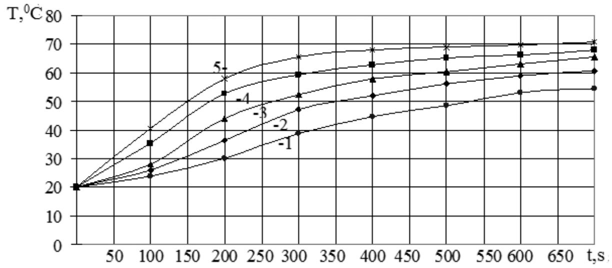

Fig. 2. Determination of the oil filtration temperature when changing the frequency of the ultrasonic oscillations of the power supply: *1* – 24 kHz, *2* – 50 kHz, *3* – 75 kHz, *4* – 115 kHz, *5* – 130 kHz

– the amount of sludge at a power of 1.3 kW emitter and different oil temperatures is shown in Figure 3.

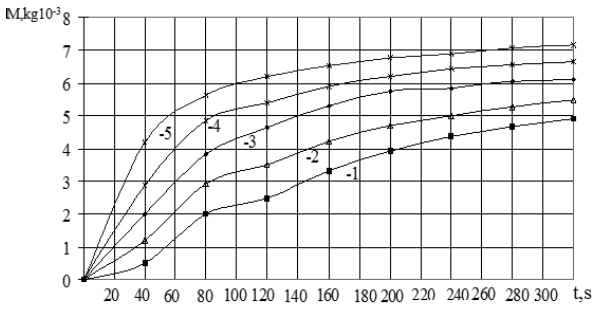

Fig. 3. Determination of the amount of precipitate in the exciter 1.3 kW and different temperature oil: *1* – 20°C; *2* – 30°C; *3* – 40°C; *4* – 50°C; 5 – 6°C, jitter frequency of the ultrasonic irradiator 120 kHz

– the amount of sludge obtained by ultrasonic oil filtration and without use is shown in Figure 4.

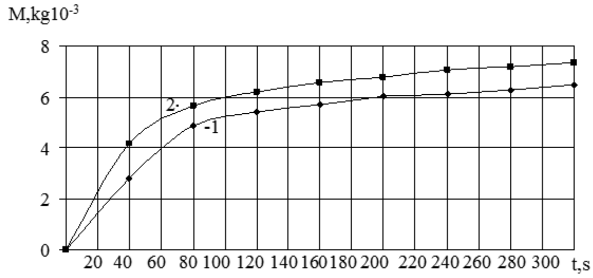

Fig. 4. Comparative analysis of the precipitate obtained: *1* – without using ultrasonic vibrations, the oil filtration temperature is 55°C; *2* – use of ultrasonic vibrations. Sonication mode: oil temperature 55°C with 1.3 kW ultrasonic vibration, ultrasonic wave frequency 120 kHz

– the amount of sludge for 200 seconds of filtration at an oil temperature of 55°C and a change in the power of the ultrasonic vibrations is shown in Figure 5.

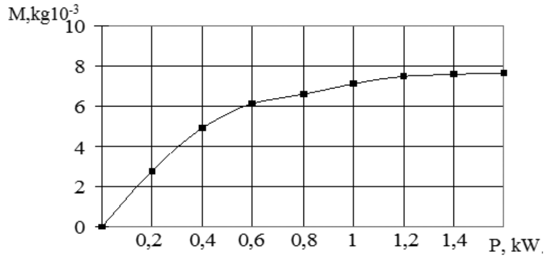

Fig. 5. Determine the filter cake for 200 seconds at an oil temperature of 55°C and change the force of ultrasonic vibrations

– amount of sludge for 200 seconds filtration and change of oil temperature is presented in Figure 6.

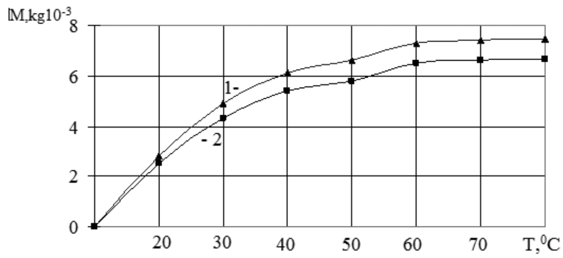

Fig. 6. Determination of sediment for 200 seconds filtration and change of oil temperature: *1* – the power of ultrasonic vibrations is 1.3 kW; *2* – without using ultrasonic vibrations

Discussion

Analyzing the experimental data obtained to determine the oil filtration temperature, changing the frequency of ultrasonic vibrations, an increase in the temperature of the oil over time increases with the emission of ultrasound waves. This can be explained by the fact that the absorption of ultrasound in a liquid medium involves transforming the acoustic energy into a thermal energy. From the family curves, it can be seen that the heating time at 24 KHz ultrasonic vibration frequency is three times higher than at 130 kHz. However, the difference in heating in the range 115-130 kHz is negligible. So we set the optimal frequency of 120 kHz.

Regarding the determination of the amount of sediment after some time of filtration at a certain frequency of ultrasonic vibrations, we see an increase in the amount of sediment over time with increasing temperature. For example, at a temperature of 20°C, the amount of precipitate obtained is 1.5 times less than at 60°C.

At a filtration temperature of 55°C without the use of ultrasonic vibrations, the difference in the amount of sediment is 10% in favor of the ultrasonic method.

When the irradiation power changes, we see the dependence of increasing the precipitation removal with increasing the power of the ultrasonic vibrations.

In the range of 0.25 to 1.5 kW, the amount of precipitate has doubled. But the increase in the amount of sludge in the range of 1-1.5 kW varies slightly; therefore, we take an optimal power of 1.3 kW. Using the obtained data, taking into account some effective parameters of the impact of the ultrasonic vibrations, we take the filtering time of 200 s. The time required is sufficient to eliminate the maximum amount of sludge with optimum power consumption.

These experimental studies (Figures 2-6) show that using ultrasonic waves in the sunflower oil filtration process, the amount of released sludge increases and process time decreases.

After the experimental studies were established the following optimal parameters of the cleaning process of sunflower oil under the effect of an ultrasonic field: power ultrasonic vibrations – 1.3 kW, frequency ultrasonic wave – 120 kHz, the processing time – 200 seconds, the temperature of the oil – 55°C. With these parameters an optimal effect is achieved for the removal of suspended substances and consequently improvement of the filtration process. Compared to conventional filtration, ultrasonic field treatment improves the removal of impurities by 12%.

Conclusion

Developed and created an experimental installation with ultrasonic generator for purification of sunflower oil under the influence of ultrasonic field.

A methodology for determining the optimal frequency of ultrasound, the ultrasound emission power and the time of purification of vegetable oils has been developed.

A basis of experimental data was developed for the studies of the sunflower oil purification process, which are presented in graphical form.

The technological parameters of the process of purification of sunflower oil by ultrasonic treatment have been determined and experimental process studies have been carried out. The optimal parameters are: power ultrasonic vibrations – 1.3 kW, the frequency ultrasonic wave – 120 kHz, the processing time – 200 s, and the temperature of the oil – 55°C. Compared to conventional filtration, ultrasonic field treatment improves the removal of impurities by 12%.

Purified sunflower oil fully meets the requirements of the State Food Quality Standard. The oil is obtained without carrying out an additional process of hydration and low temperature processing. This leads to an improvement in the energy performance of the purification process, which uses fewer machines and equipment.

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