Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

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Odesa National University of Technology, 2022.

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INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

4. POWER ENGINEERING AND ENERGY EFFICIENCY

DEVELOPMENT OF ENERGY-EFFICIENT VIBRATION PLANT FOR DRYING SUNFLOWER SEEDS BASED ON INFRARED RADIATION

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Abstract. *Currently, drying of food materials by infrared (IR) radiation becomes widespread. The technology of dehydration of products and materials is far ahead of the theoretical drying conditions. Not only classical literature on problems of drying, but also special does not give concrete recommendations for the design of installations with electromagnetic energy supply. Therefore, until the only reliable way of their study is an experiment. Despite the great scientific amount of literature on drying, including on IR-installations, practical issues of designing infrared dryers have not been worked out. Well-known studies are exclusively private.*

The technological features of drying sunflower seeds by means of infrared energy supply are described, and the prospects of vibration monolayer drying of sunflower seeds are grounded. The specific energy costs are determined for the process of infra-red drying of the product.

Keywords: *sunflower, infrared irradiation, vibrolot drying.*

I. INTRODUCTION

In the system of processing operations after harvesting of sunflower, the most important place belongs to drying. Quality of drying not only ensures the storage of the harvested crop, prevents its loss, but in some cases also improves the quality of the finished product.

The freshly harvested sunflower seeds are very resistant to storage, especially at high humidity, temperature and debris. When storing seeds, chemical changes have primarily fats, and then protein substances.

High-polluted sunflower seeds are safely stored if their humidity does not exceed 7%, and the temperature is lowered to 10 ° C and lower. At humidity above the critical and the temperature of 20 ... 25 ° C, in the pile seed begins a rapid development of microorganisms, intensive hydrolytic and oxidative processes occur. Such processes lead to a rapid deterioration of the quality of sunflower seeds as an oilseed. Even a few hours of storage of freshly collected high-oiled sunflower seeds with a moisture above the critical one leads to massive self-heating and spoilage, which makes it impossible to produce high-grade oils [1].

At the present stage, with the emergence of farm and rental companies, new requirements have been created for the technology used for post-harvest treatment and, in particular, the drying of cereals and oilseeds. Farmers tend not only to grow a good harvest, but also to bring it to a state suitable for implementation or long-term storage.

The grain should have the necessary moisture, maintain its nutritional properties and seed quality. The cost and timing of drying services on elevators do not suit the farmers. Special problems arise when drying elite seed grain, which is produced in relatively small batches and requires a strict savings mode of drying and does not allow mixing with other varieties.

To solve this problem dryers with infra-red energy supply differ from the known by high efficiency and speed of drying, simplicity of structure and operation, quality of work and flexibility of technological process of drying control. When crops of grain in a farm from 100 to 300 hectares, the presence of such a dryer will increase the efficiency of the technological process after grain harvesting. The proposed type of grain dryer can also be used effectively in grain mills.

The prospects of using infrared drying of freshly harvested sunflower seeds are due to the fact that this drying method is quite high intensity, economical and allows you to maintain the nutrient and seed quality of the seeds. In addition, there is no need to use air as a thermal agent, which significantly reduces the energy consumption of the drying process. Promising in this sense is a combination of infrared heat conduction and active contact of seeds with unheated air, which provides, for example, a vibro boiling layer. The use of infrared heat removal for the drying of sunflower seeds is also facilitated by the black husk color and the relatively small thickness of sunflower seeds, which, under certain regime parameters, can provide infrared rays penetration into the central layers of the nucleus.

II. LITERATURE ANALYSIS

Analysis of recent research and publications. Infrared (IR) drying has become one of the potential applications to the general drying method because of its advantages such as the simplicity of the required equipment, the easy placement of IR drying with conductive convective and microwave methods, higher heat transfer rate, energy saving and fast transient response [2, 3].

Infrared drying implies irradiation of a moist material in the range of wavelengths of 0.8-1000 μm of electromagnetic radiation [4]. Many researchers have been studying IR drying as a potential method for obtaining high quality dried fruits, vegetables and grains [5, 6]. Numerous studies have been conducted to improve the efficiency of heating and obtaining high quality dry food products [7, 8, 9].

When using infrared radiation to dry the moist materials, the rays pass through the material, penetrate into it, and the radiation energy is converted into heat [10].

The energy efficiency of infrared dryers is directly related to the absorption characteristics of the material, which determines the economic feasibility of the dryer [11]. Infrared drying is a method of dehydration that has high-energy efficiency. This means that the energy savings of an IR dryer are greater than that of convection and other drying methods. Given the distance between the heating source and the material, the air flow rate and temperature, as well as the material speed (if a continuous IR dryer) can have a significant effect on energy efficiency.

The transmission of infrared energy is carried out without heating the ambient air so there is no need for a heating medium between the source of energy and the material in IR dryers. Because of the rapid and uniform heating, the infrared radiation penetrates directly into the inner layer of the material without heating the surrounding air, and the energy consumption of infrared drying is lower than other methods [12, 13]. Summing up and analyzing the experiments of other researchers, we can conclude that an increase in the power level of infrared radiation leads to a reduction in the drying time, while an increase in air velocity leads to an increase in drying time and energy consumption. By increasing the air speed, the surface layer becomes cool and requires longer drying time. Thus, the air velocity must be adjusted to provide better results. The power level of infrared radiation should also be adjusted, since increasing power can lead to loss of quality. In addition, there are other factors that were not considered by the researchers such as the effect of vibration on the drying process in IR dryers.

Researchers of the Institute of Cold and Biotechnology in St. Petersburg [14] conducted a study of the process of drying sunflower seeds of the seed fund with infrared radiation of the selected wavelength when reaching the specified moisture content and temperature, which does not exceed 44-46 °C on the surface of the layer of the treated material, depending on the height the product layer, the density of the heat flow, the distance from the infrared emitter to the product. From the analysis of experimental curves it can be seen that the moisture content of sunflower seeds during the whole drying process decreases with time over linear law, while the temperature in the center of the product layer does not exceed 44-46 °C. However, the researchers [14] did not apply the vibratory effect of grain transfer along the tray dryer.

The work [4] studied the drying characteristics of three varieties of high-volatile rice varieties (slenderness, shankar and basmati) using serial vibration infra-red dryer with a radiation intensity of 3100 and 4290 W /m^2 and a depth of 12 and 16 mm grain layer. They found that the drying rate depends on the intensity of the radiation, the drying occurred during the fall, and the period of constant velocity was not observed. At a given temperature of air for drying (40 ° C), the increase in the intensity of infrared radiation reduced the drying time in both fixed and vibration modes.

Researchers in the work [15] also emphasized that one of the methods of rapid and uniform drying of grain is vibration.

In the work [16], the processes of radiation-convective heat and mass transfer between all the defining objects inside the vibration dryer with IR-power supply are theoretically substantiated. On the basis of thermal and material balances, the equations that describe the main dynamic characteristics of the drying conditions of oily grain material in a continuously operating IR dryer are determined. Due to the fact that the exact analytical solution of the presented mathematical model in the form of a system of differential equations in partial derivatives does not exist. The proposed solution allows to identify dependencies of temperature distribution and moisture content of grain and oil-bearing material on the length of the dryer at any time.

The work [17] proposed technologies of targeted energy delivery for the intensification of heat and mass transfer during the processing of food raw materials. The basis of the proposed hypotheses is the wave technologies of the combined electromagnetic and vibrational action. Mechanisms, effects and mathematical models of barodiffusion and actions of vibration fields are grounded. The numbers of wave similarity are proposed, on the basis of which the bases of experimental data on drying are summarized.

Many studies have been carried out on thin-layer drying of food products using different methods of dressing and drying methods such as soya [18], crushed rice [19], hybrid rice seeds [20], but very little information for vibration infrared drying sunflower seeds.

In spite of the fact that air in IR-drying is not a coolant, it has a significant impact on the efficiency of heat exchange radiation. The lower the temperature difference between the air and the irradiated surface, the lower the temperature gradient in the material and its uniform heating. A large temperature gradient inside the drying body (seeds, grains) often causes its destruction - the appearance of cracks, deformations, and the like. Therefore, as a rule, in installations for radiation drying the temperature difference between the air and the material to be dried should be limited.

We conducted research on a "vibration thermo radiation" monolayer "oscillating" heating dryer, using which, according to laboratory studies, it is possible to achieve a lower specific energy consumption in comparison with traditional dryers by about 1.5-2 times [21]. In it to reduce humidity of products by 6-8%, with its one-time heating, in the chamber over the thermal tray it is necessary to create sufficiently high temperatures (up to 200-250 ^{o}C), while the particles of products are warmed up to a temperature of 140-180 ^{o}C, which is unacceptable oh for many kinds of grain products, especially for seed grain. Therefore, in further studies, for the reduction of the temperature of the heating of the product particles, with the least decrease in its moisture content, it was proposed [22, 23] to use "oscillating" heating with infrared rays. In it the heating periods alternate with the periods of cooling by cold air, and an electromechanical debalanced vibration drive is used to excite oscillations.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of the work is to study the kinetics of the technological process of drying sunflower seeds by infra-red irradiation in a vibrolot mono dryer.

Object of research: the process of drying sunflower seeds in a vibrating dryer with infrared energy supply.

Subject of research: vibration tray dryer and regularities of change of parameters of drying of sunflower seeds in the conditions of a vibroweighted layer of production.

Materials and methods of research. Experimental-industrial sample of a vibration machine (fig. 1) for drying sunflower seeds, allows a wide range of drying temperature control (from 20 to 180 ^{o}C), the air velocity varies within 0, 5 ... 2.5 m / s, oscillation amplitude of the vibrolot (from 0.5 to 6 mm).

Technical characteristics of laboratory vibration dryers

Productivity, kg / h.	110;
Power of the electric car, kW	5,0;
Power vibration drive of the lot, kW	0,5;
Amplitude of oscillations of the vibrolot, mm	0-6;
Frequency of rotation of the driving electric motor, rpm.	910;
Temperature in the thermocouple, ^{o}C	20-180;
Weight, kg	230;
Overall dimensions, mm	1400x600x3000;

The basic scheme of such a drying machine is shown in Fig. 1. The machine consists of a closed shell housing 1, on the sites 2 of which with the help of elastic elements 3 installed thermal 4 and grate 5 lots. The work path of the thermal tray 4 is made of heat-resistant sheet steel. The working path of the grate tray is formed by longitudinal vertical strips 7 welded to the brackets 8 so that there is a longitudinal clearance δ = 1.5 ... 2 mm between them. In the middle of each tray mounted vibration drive, containing two centrifugal vibro-accelerators mounted on the sides of the lot.

Each centrifugal vibrator has a shaft with unbalanced loads 9 which, by means of an elastic muffle 10, is connected to an actuating asynchronous electric motor 11. Moreover, in each vibration drive, the electric motors 11 are connected in such a way that, when connected to the network, their rotors are rotated toward each other. Shafts with unbalanced loads 9 are installed on the bearings parallel to each other at an angle β to the planes of the work tracks of the trays. Above the surfaces of thermal trays 4 fixed heat generators 12 (infrared emitters). At the top and on the sides, the thermal tray 4 is covered with thermal insulation 13. Above the start of the thermal tray 4, the feed bottle 14 is fixed, and at the end of the impeller 15, at the beginning of the grate tray 5, there is a discharge nozzle of the fan 16, and above the grate pan 6, the outlet pipe 17 with the adjusting the shaft 18. At the end of the grate tray 5, the receiving hopper 19 was installed.

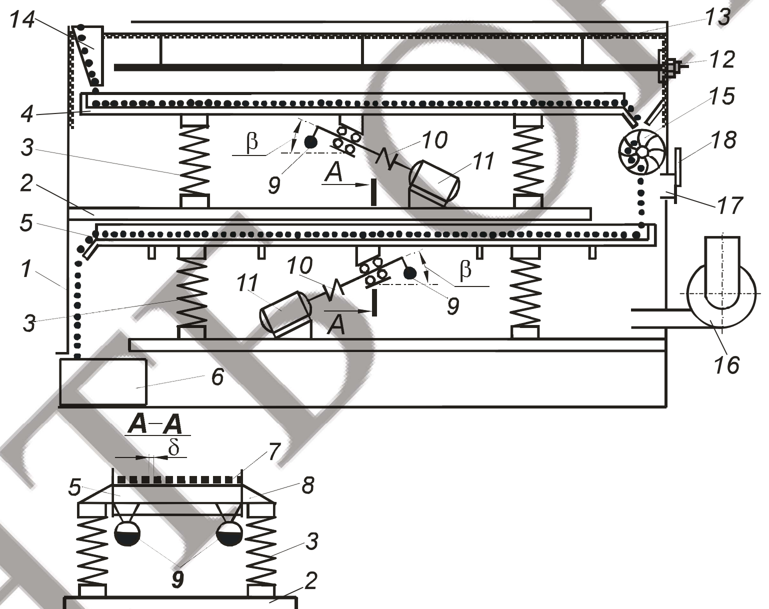

Fig. 1. Scheme of laboratory infrared monochrome vibration dryer:

1 - body; 2 - site; 3 - elastic elements; 4 - thermal lot; 5 - Grain lot; 6 - receiving hopper; 7 - longitudinal vertical stripes; 8 - bracket; 9 - debalanced cargo; 10 - elastic coupling; 1- - electric motor; 12 - thermogenerators; 13 - thermal insulation; 14 - feed throat; 15 - impeller; 16 - fan; 17 - outlet pipes; 18 - adjusting sider.

The machine works this way. When actuating electric motors 11, their rotors begin to rotate towards each other in each vibration drive, which leads to a dynamic synchronization of their rotation, resulting in the translational vibrations of trays 4 and 5 at an angle β to the planes of their work paths. Bulk products are fed through the loading neck to the surface of the lots, where the vibration is distributed by a mono layer. Under the influence of the vibrations of trays between their surfaces and particles of bulk products there is an asymmetry of frictional forces, which leads to the directed movement of particles of bulk products (vibration transport) along the surface of the lots. At the same time, the points of the surface of the trays fluctuate relative to some center without directed motion in general for the period of one oscillation. By changing the static moments of the unbalanced cargoes 9 relative to the rotation axis, a vibration transport mode is established with the continuous dumping of the particles of bulk products during their movement along the trays. Continuous pouring of product particles leads to their chaotic scrounging when moving along thermal trays 4 above which there are thermogenerators 12 and contributes to their uniform irradiation on all sides with infrared rays, which leads to intense, rapid and uniform heating of sunflower seeds.

Fig. 2. Photo of experimental vibroplot infra-red dryer
(impeller, outlet pipes, regulating sider on the photo not shown)

After passing the thermal lot, the heated products (sunflower seeds) are fed through the drum impeller 15 to the grate lot 5, which is blown by the atmospheric air from the fan 16. In this case, the continuous chaotic throwing and turning of the product particles also improves the uniformity of their air by blowing. It leads to disturbance of the equilibrium state of moisture in product particles, when the pressure of water vapor in them becomes greater than the partial pressure of water vapor in the air, as a result of which moisture begins to intensively evaporate [22, 23]. The processed products, after passage of the grate tray 5, are fed into the receiving hopper 19. The drum impeller 15 prevents access of the cold air from the fan 16 to the high temperature chamber over the thermal lot 4 and at the same time allows the product to wake from the heat lot 4 to the grate 5. The airflow intensity is controlled by a sider 18. The speed of vibration transport of bulk products, and therefore the time of its location on the tray surface is regulated by changing the static moments of unbalanced cargoes 9 relative to and their rotation or angle β. Since the infrared radiation of the thermogenerator 12 can create a very intense heat flux, which facilitates the rapid heating of the product particles, and the process of evaporation from them requires more time, the speed of vibration transport on the grate tray 5 is set higher, and it is made with wider work paths.

The infrared heater consisted of 20 infrared lamps of 250 W (OSRAM, Slovakia), located in a drier in a chess manner. The distance between the lamps, at which the maximum uniformity of the energy irradiance of the surface of the dried material is achieved, is 0.12 m. The lamps are powered by a 220 V power supply. The infrared lamps can be located 5 ... 15 cm away from the surface of the lot.

Humidity of sunflower seeds is determined by drying the samples to a constant mass. Samples were taken before and after infrared irradiation and airflow.

The product loading bin is equipped with a gateway that regulates the thickness of the product monolayer on the lot within the range of 7 ... 22 mm, depending on the size of the grain and the speed of its movement on the lot.

The intensity of the infrared radiation varied by changing the distance between the lamps and the surface of the reception. Also, to achieve the required uniform levels of intensity of infrared radiation, the aforementioned distance was regulated manually, changing the height of the suspension of the lamp body. To ensure the uniformity of infrared radiation over sunflower, preliminary measurements were made prior to the main tests.

The weight of the grain was determined by the electronic weights TWE-0,21-0,01. The temperature of the product was measured remotely by the Laserliner pyrometer. The change in the mass of grains before the study and after determining the mass of sewage.

The experiments recorded the length of the process, the temperature and mass of sunflower in the beginning and at the end of the treatment. Specific mass of material (g) shows the mass (m) of the product per unit surface treatment (F), and specific power - the IR-energy, which is spent on 1 m2 of the treated surface.

Experiments were conducted at room temperature of 20 ° C, relative humidity of 65% in the room. The influence of the energy of the energized energy on the average speed of the drying process was studied. Experiments were carried out at a rate of grain movement per lot 0.025 m/s, and a specific load of 4.11 kg/m^2. The amount of moisture was determined by the initial and final humidity of sunflower. The drying rate was calculated based on the amount of moisture and the time during which sunflower was affected by infrared radiation.

Table1. Range of the process of IR – drying study

Raws	Specificpower IR, kW / m^2	Temperature, T, ° C	Download, *g*, kg/m^2	Duration process t, min
Sunflower seeds	**2,0…5,0**	**33…43**	**4,11…8,22**	**30…60**

The mass flow rate of the inlet air was provided by the fan and controlled by an electric inverter (N50-007SF, Korea). Air velocity for all experiments was measured using TESTO Anemometer 425 (Germany) with an accuracy of ± 0.03 m/s. The speed of air varies within 0.5 ... 2.5 m/s by adjusting the fan engine speeds. The initial moisture content of sunflower seeds was 17 ± 0.5%. In total, 34 experiments were performed on combinations of three levels of infrared radiation (2000, 3000, 5000 W/m^2) and vibration (24 Hz)). To measure the change in humidity during drying, the vibrolot dryer was stopped and samples were taken at a time interval of 7 minutes.

IV. RESULTS

Any modernization of the dryer can be considered quite effective if the reduction of specific energy consumption (with the obligatory preservation of product quality) is achieved.

Parameters of IC-drying sunflower seeds recommended by OSRAM lamps on the basis of experimental studies should be considered: height of hanging infrared emitter during drying of grain h = 0,1 m; t_{min} = 35 °C to t_{max} = 43 °C. With an increase in specific power by 2.5 times (Fig. 3), the drying process decreases in proportion.

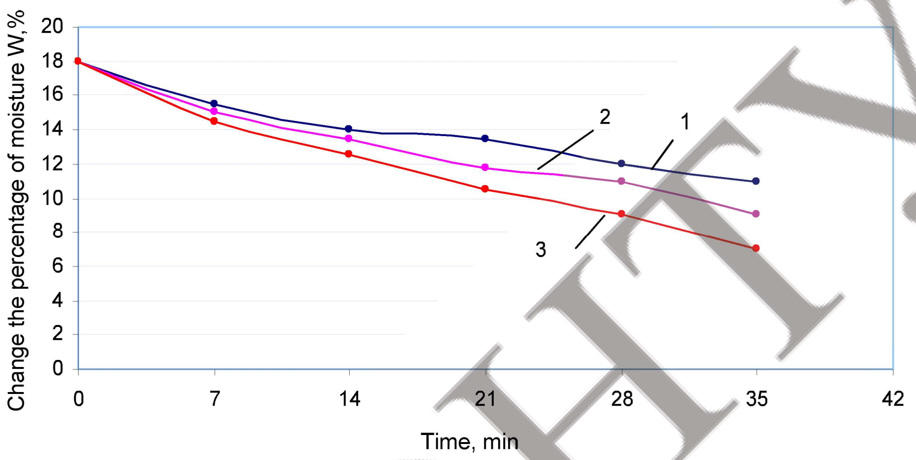

Fig. 3. Effect of specific power on kinetics of drying
where, 1 - N = 2000 W / m²; 2 - N = 3000W /m²; 3 - N = 5000W / m².

The drying time to the relative humidity of the product in 6-7% takes 35 ... 60 minutes. The data (fig. 3) determined the values of the drying rate (Fig. 4).

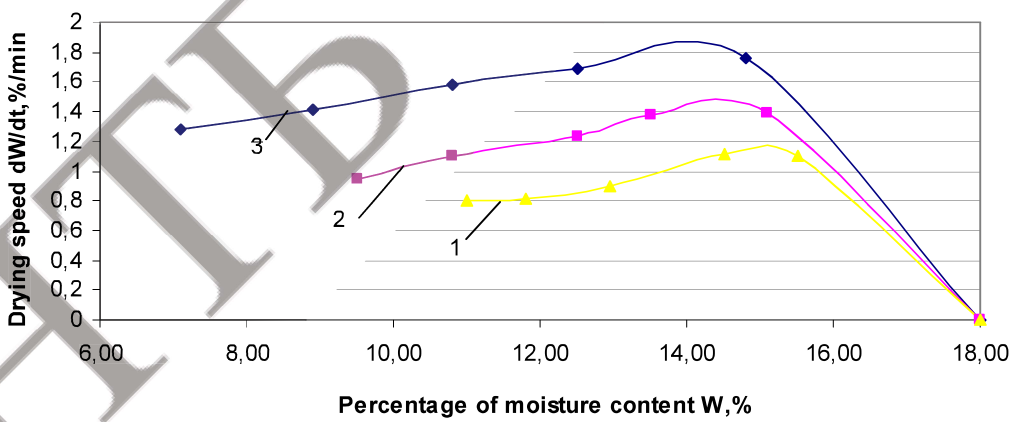

Fig. 4. Effect of specific power on the speed of drying
where, 1 - N = 2000 W / m²; 2 - N = 3000 W / m²; 3 - N = 5000 W / m².

It can be seen (Fig. 4) that when the amount of energized energy is increased by 2.5 times, the drying rate increases by 50%. The drying rate varies within 1 ... 2,15% / min. The productivity of the installation in a loading mode of 4,11 kg / m² at a rate of grain movement per tray 0,016 ... 0,025 m / s was 80 ... 110 kg / h of dry grain with a moisture content of 6,5%. At the same time, at an increase in the power of 2.5 times the increase in the temperature of sunflower seeds at the outlet does not exceed 43 °C (Fig. 5), which is very important in the process of drying sunflower seeds.

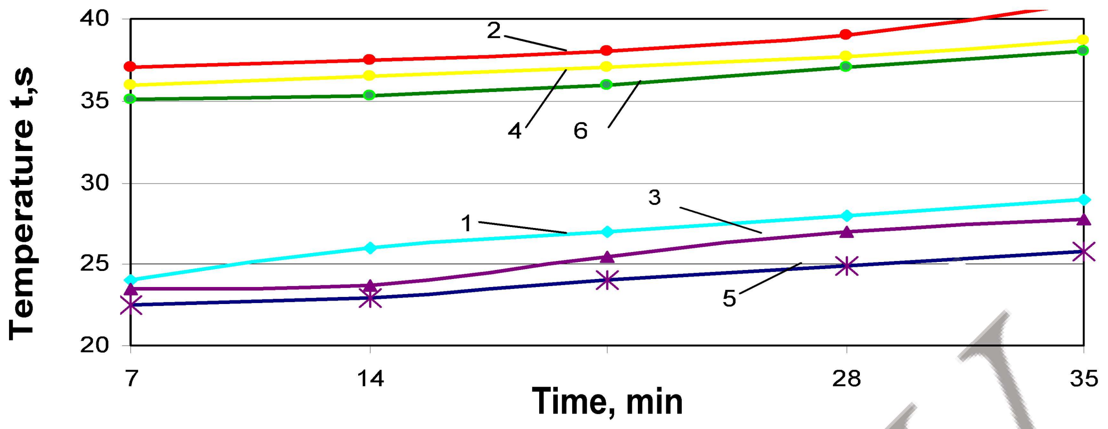

Fig. 5. Effect of specific power on product temperature.

where, 1 - the product temperature at the input to the dryer at N - 5000 W / m^2;
2 - the product temperature at the outlet of the dryer at N -5000 W / m^2;
3 - the product temperature at the entrance to the dryer at N -3000 W / m^2;
4 - the product temperature at the outlet of the dryer at N-3000 W / m^2;
5 - the product temperature at the input to the dryer at N -2000 W / m^2;
6 - the product temperature at the outlet of the dryer at N -2000 W / m^2;

The drying machine described above reduces the specific energy consumption by approximately 1.5-2 times compared with convection shaft driers, retains all the advantages of the laboratory infrared monochrome vibration dryer described above. At the same time, the maximum temperature of the heating of particles of products is 1.5 - 2 times less with larger limits of their humidity. This allows for higher quality production of products at lower heat costs.

However, since the output moisture content of loose products may fluctuate within very wide limits, in order to regulate the speed of vibration transport of bulk products along the vibrolots, and therefore the time of their processing on each tray, it is necessary to adjust the parameters of the vibrations of the lot by changing the magnitude and frequency of oscillations of the force to provide energy saving resonance mode of vibration drying. To solve this problem, it is possible to use [24] or an debalanced controlled vibration drive with an adjustable magnitude of static imbalance, or an unbalanced vibration drive in which a wide-pulse frequency governor of a three-phase alternating current is used for feeding the electric motors. It allows you to adjust the angular speed of the drive motors (and therefore, to maintain the resonant frequency of oscillations of the vibrocolots and to adjust the magnitude of the force of the vibrational stimulator).

V.CONCLUSIONS

1. Complex experimental research on the influence of regime parameters (specific load and power) on the kinetics of IR drying of sunflower seeds in a vibration laboratory infrared monochrome vibration dryer was performed.

2. With an increase in specific power in 2,5 times the drying process decreases in proportion. The drying time to the relative humidity of the product at 6-7% takes 30

... 60 minutes. The average temperature of the product was within 35-43 ºC. There was no cracking of the husk.

3. Parameters of IC-drying sunflower seeds recommended by OSRAM lamps on the basis of experimental studies should be considered: height of hanging of infrared emitter during drying of grain h = 0,1 m; t_{min} = 35°C to t_{max} = 43°C.

4. Vibration monolayer dry intermittent infra-red heating allows to reduce the specific energy consumption approximately in 1,5-2 times, in comparison with the convection dryer, retains all the advantages of laboratory infrared monochrome vibration dryer. At the same time, the maximum temperature of the heating of particles of products is 1.5 - 2 times less with larger limits of their humidity. This allows for higher quality production of products at lower heat costs.

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