RESEARCH ON SUNFLOWER SEEDS DRYING PROCESS IN A MONOLAYER TRAY VIBRATION DRYER BASED ON INFRARED RADIATION
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ДОСЛІДЖЕННЯ ПРОЦЕСУ СУШІННЯ ЗЕРНА СОНЯШНИКУ У МОНОШАРОВІЙ ЛОТКОВІЙ ВІБРОСУШАРЦІ НА ОСНОВІ ІНФРАЧЕРВОНОГО ОПРОМІНЕННЯ

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***Keywords**: drying, sunflower, infrared radiation, vibrotray drying.*

ABSTRACT

Currently, drying of food materials by infrared radiation (IR) 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 literature does not give concrete recommendations for the design of installations with electromagnetic energy supply. Therefore, the only reliable way of their study is an experiment. Despite the great scientific amount of literature on drying, including 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 in this paper and the prospects of vibration monolayer drying of sunflower seeds are grounded. The specific energy costs are determined for the process of infrared drying of the product.

РЕЗЮМЕ

В даний час набуває широкого поширення сушіння харчових матеріалів інфрачервоним (ІЧ) випромінюванням. Техніка зневоднення продуктів і матеріалів значно випереджає теоретичні положення сушіння. Не тільки класична література з проблем сушіння, але і спеціальна не дають конкретних рекомендацій з проектування установок з електромагнітним підведенням енергії. Тому поки єдиним надійним шляхом їх дослідження є експеримент. Незважаючи на велику наукову літературу по сушінню, в тому числі і по ІЧ-установкам, практичні питання проектування ІЧ-сушарок не опрацьовані. Відомі дослідження носять виключно приватний характер.

В роботі описані технологічні особливості сушіння зерна соняшнику за допомогою інфрачервоного підведення енергії, та обґрунтовано перспективність вібраційного моношарного сушіння насіння соняшнику. Визначені питомі затрати енергії на процес інфрачервоного сушіння продукту.

INTRODUCTION

In the system of processing operations after sunflower harvesting, 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 have low resistance 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 lower than 10°C. At high humidity and temperatures between 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 sunflower seeds quality. 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 (*Stankevich, G.M., 2003*).

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 infrared energy supply differ from the known ones by high efficiency and speed of drying, simplicity of structure and operation, work quality and flexibility of technological process of drying control. However, the drying process itself, and the machines that provide it, require further research, in order to control their rational parameters. When, in a farm, there are grain crops 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 of quite high intensity, economical and allows you to maintain seed nutrient and quality. 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 sunflower seeds drying is also facilitated by the black husk colour 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.

MATERIALS AND METHODS

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 (*Boudhrioua et al., 2009; Basman and Yalcin, 2011*).

Infrared drying implies irradiation of a moist material in the range of wavelengths of 0.8-1000 μm of electromagnetic radiation (*Das et al., 2009*). Many researchers have been studying IR drying as a potential method for obtaining high quality dried fruits, vegetables and grains (*Ruiz Celma et al., 2009a; Khir et al., 2011*). Numerous studies have been conducted to improve the efficiency of heating and obtaining high quality dry food products (*Wang and Sheng, 2006; Zhu et al., 2010; Dondee et al., 2011*)

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 (*Pan et al., 2008*).

The energy efficiency of infrared dryers is directly related to the absorption characteristics of the material, which determines the economic feasibility of the dryer (*Pawar and Thorat, 2011*). 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 it's 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 (*Swasdisevi et al., 2009; Arsoy, 2008*). Summing up and analysing 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.

The work of *Das et al., (2009*), studied the drying characteristics of three varieties of high-volatile rice varieties (slenderness, shankar and basmati) using serial vibration infrared 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 of *Nourmohamadi- Moghadamiet al., (2017*), also emphasized that one of the methods of grain rapid and uniform drying is vibration.

In the work of *Bandura et al., (2018*), 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 identifying dependencies of temperature distribution and moisture content of grain and oil-bearing material on the length of the dryer at any time.

The work of *Burdo et al., (2017*), 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, based on which the bases of experimental data on drying are summarized.

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 our research on a "vibration thermo radiation" monolayer "oscillating" heating dryer. According to laboratory studies, it is possible to achieve lower specific energy consumption in comparison with traditional dryers by about 1.5-2 times (*Rogov and Nekrutumman, 1976*). In order to reduce the 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 for many kinds of grain products, especially for seed grain. Therefore, in further studies, for the reduction of the product particles heating temperature, with the least decrease in its moisture content, it was proposed (*Yaroshenko, 2002; Goncharevich, 1972*) to use "oscillating" heating with infrared rays. In this case the heating periods alternate with the periods of cooling by cold air, and an electromechanical unbalanced vibration drive is used to excite oscillations.

The purpose of the work is to study the kinetics of the technological process of drying sunflower seeds by infrared irradiation in a vibrotray mono dryer.

Experimental-industrial sample of a vibration machine (fig. 1) for drying sunflower seeds, designed and manufactured in the laboratory of technological processes automation of Vinnytsia National Agrarian University, 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 and the oscillation amplitude of the vibrotray varies from 0.5 to 6 mm.

Technical characteristics of laboratory vibration dryer:

Productivity, kg/h	110;
Power of the electric machine, kW	5.0;
Power vibration drive of the lot, kW	0.5;
Amplitude of vibrotray oscillations, mm	0-6;
Rotation frequency 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 basic platforms *2* of which, with the help of elastic elements *3*, are installed two solid heating *4* and two perforated grate vibrotrays *5*.

The work path of the thermal tray *4* is made of heat-resistant steel sheet. 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. Inside of each tray, there are mounted vibration drives, containing two centrifugal vibro-exciters mounted by the sides of the tray.

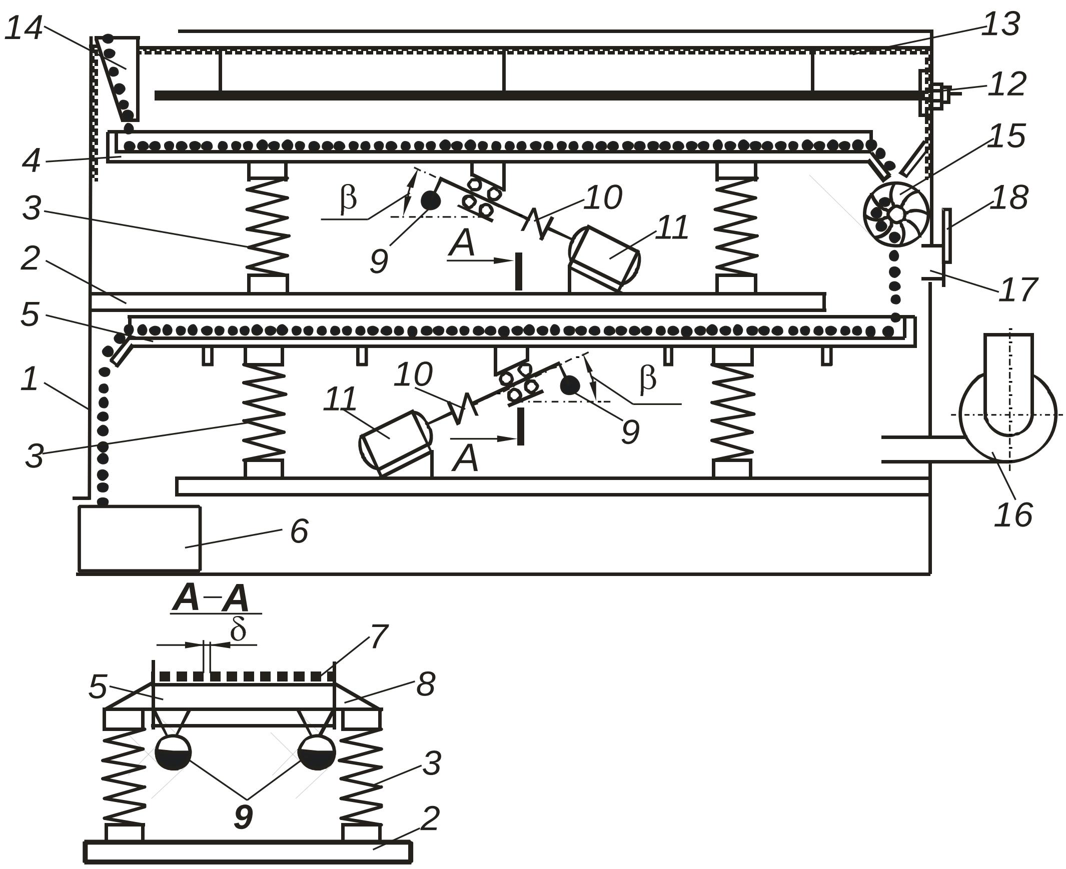

Fig. 1 - Scheme of laboratory infrared monochrome vibration dryer

1 - body; 2 - platform; 3 - elastic elements; 4 – heating tray 5 - grain tray 6 - receiving tank; 7 - longitudinal vertical stripes; 8 - bracket; 9 - unbalance load; 10 - elastic coupling; 11 - electric motor; 12 – thermo-generators; 13 - thermal insulation; 14 - feeding throat; 15 - impeller; 16 - fan; 17 - outlet pipes; 18 - shutters.

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 trays work tracks. Above the surfaces of the thermal trays *4* are 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 feeding throat *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 tray *5*, the outlet pipe *17* with the adjusting shutter *18*. The receiving tank *6* was installed at the end of the grate tray *5*.

The machine works in the following way. When activating electric motors *11*, their rotors start to rotate towards each other in each vibration drive, which leads to a dynamic synchronization of their rotation and the emergence of a directed forcing power. Therefore, the reciprocating vibrations of the trays *4* and *5* are formed at an angle *β* to the planes of their work paths (in the direction of the forcing power). Bulk products are fed through the feed throat to the surface of the trays, where the vibration is distributed by a mono layer. Under the influence of trays vibrations 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 trays. At the same time, the points of the trays surface fluctuate relative to some centre 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 whirlabout when moving along thermal trays *4* above which there are thermo-generators *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 vibrotray infrared dryer
(impeller, outlet pipes, regulating sider on the photo not shown)

After passing the thermal lot, the 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 blowing them with air. It leads to disturbance of the equilibrium state of moisture in product particles, when the pressure of water vapour in them becomes greater than the partial pressure of water vapour in the air, as a result of which moisture begins to intensively evaporate (*Yaroshenko, 2002; Goncharevich, 1972*). The processed seeds are fed into the receiving tank *19*. The drum impeller *15* prevents access of the cold air from the fan *16* to the high temperature chamber over the heating tray *4* and at the same time allows the product to be moved from the heating tray *4* to the grate *5*. The airflow intensity is controlled by a shutter *18*. The speed of vibration transport of loose products, and therefore the time it is located on the surface of the trays, is regulated. The regulation is carried out by changing the static moments of the unbalance loads *9* relative to the axis of rotation, or the angle of the oscillation direction of the vibrating trays β. Since the infrared radiation of the thermo-generator *12* can create a very intense heat flow, which facilitates the rapid heating of the product particles, and the process of evaporation 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 the drier in a chess manner. The distance between the lamps, at which the maximum uniformity of the energy irradiance of the dried material surface 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 tray.

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

The product loading tank 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 tray.

The intensity of the infrared radiation varied as the distance between the lamps and the reception surface changed. Also, to achieve the required uniform levels of intensity of infrared radiation, the before mentioned 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 and after drying determined the mass of the evaporated liquid.

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) ranged from 4.11 to 8.22 kg/m^2, shows the product weight (m) per unit processing surface (F) and specific power from 2.0 to 5.0 kW/m^2 – IR-energy consumed per 1 m^2 of treated surface. Experiments were conducted at room temperature of 20°C, relative humidity of 65% in the room. The influence of the IR-power 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.

Table 1

Range of the process of IR - drying study

Raw material	Specific power 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 vibrotray dryer was stopped and samples were taken at a time interval of 7 minutes.

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.

The parameters of IR-drying for sunflower seeds recommended by OSRAM lamps on the basis of experimental studies are: 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.

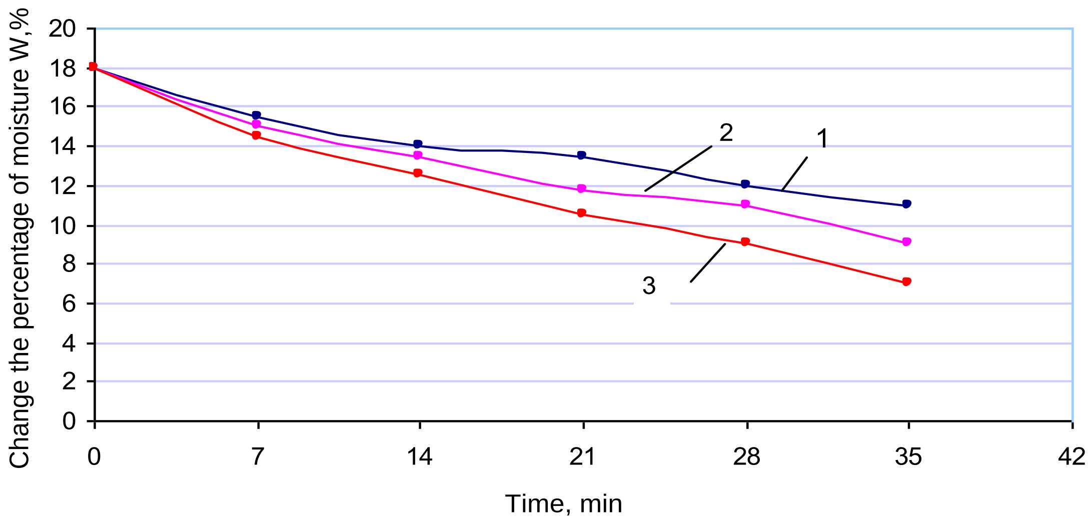

Fig. 3 - Effect of specific power on kinetics of drying

1 - N = 2000 W / m^2; 2 - N = 3000 W /m^2; 3 - N = 5000W / m^2.

The conducted analysis and experimental research suggest that the use of infrared irradiation for drying oilseed raw materials has significant prospects. It is shown that with an increase in the specific power of infrared radiation, the removal of moisture from the product increases over the same period of time.

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

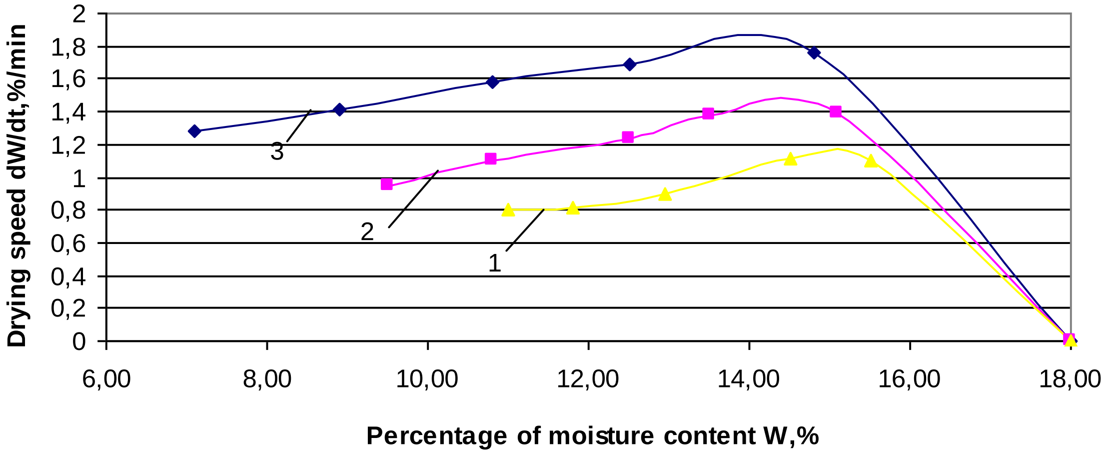

Fig. 4 - Effect of specific power on the drying speed
1 - N = 2000 W / m²; 2 - N = 3000 W / m²; 3 - N = 5000 W / m².

It can be seen (Fig. 4) that, when the amount of IR-power 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/m^2 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, for an increase of power of 2.5 times the increase in the temperature of sunflower seeds at the outlet does not exceed 43^{o}C (Fig. 5), which is very important in the process of drying sunflower seeds.

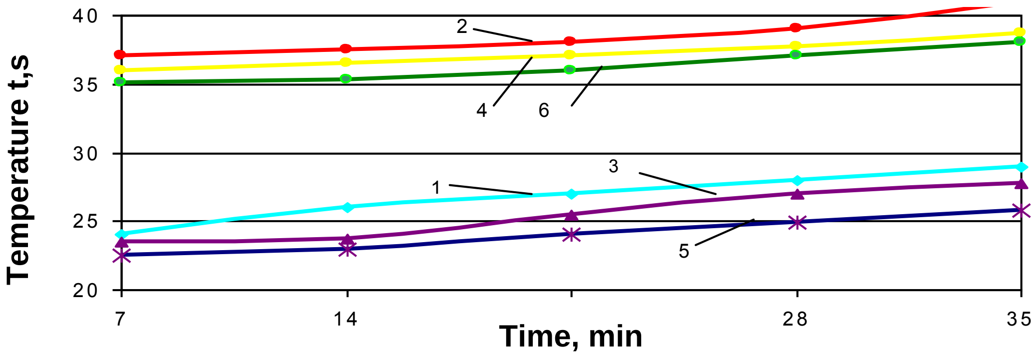

Fig. 5 - Effect of specific power on product temperature
1 - the product temperature at the input to the dryer at N - 5000 W / m²;
2 - the product temperature at the outlet of the dryer at N -5000 W / m²;
3 - the product temperature at the entrance to the dryer at N -3000 W / m²;
4 - the product temperature at the outlet of the dryer at N-3000 W / m²;
5 - the product temperature at the input to the dryer at N -2000 W / m²;
6 - the product temperature at the outlet of the dryer at N -2000 W / m²;

On the basis of the conducted researches the principal scheme of the vibrotray monolayer dryer of intermediate infra-red heating is proposed in Fig. 6. The machine consists of a closed shell housing *1*, on the basic platforms *2* of which, with the help of elastic elements *3*, are installed two (or more) solid thermal *4* and two (or more) perforated grate lots *5.*

The trays are installed under each other, so that the thermal trays *4* alternate with the tray, with the top (first) tray heating and the bottom cooling. The working tracks of the heating trays *4* are made of heat-resistant sheet of steel. The working tracks of the grate strips are formed by longitudinal vertical strips *7* welded to the brackets *8*, in order to have a longitudinal clearance d = 1.5 ... 2 mm between them. In the middle of each tray is mounted the vibration drive, containing two centrifugal vibro-accelerators mounted on the sides of the tray. Each centrifugal vibrator has a shaft with unbalance loads *9,* which, by means of an elastic coupling *10*, is connected to a driving asynchronous 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 towards each other. Shafts with unbalance loads *9* are installed on the bearings parallel to each other at an angle *β* with the planes of the work tracks of the trays. Above the surfaces of the thermal trays, *4* there are thermo-generators fixed.*12*. On top and on the sides, the thermal trays *4* are covered with thermal insulation *13*. Over the first of the thermal trays *4*, there are feeders *14* fixed, and at the end of the drum − impellers *15*. Below the surfaces of the grate bar *5* are located the nozzles of the fans *16* and above the surface of the grate bars *5* - the outlet pipes *17* with the adjusting shutters *18*. At the end of the lower grate tray *5,* the receiving tank *19* is installed.

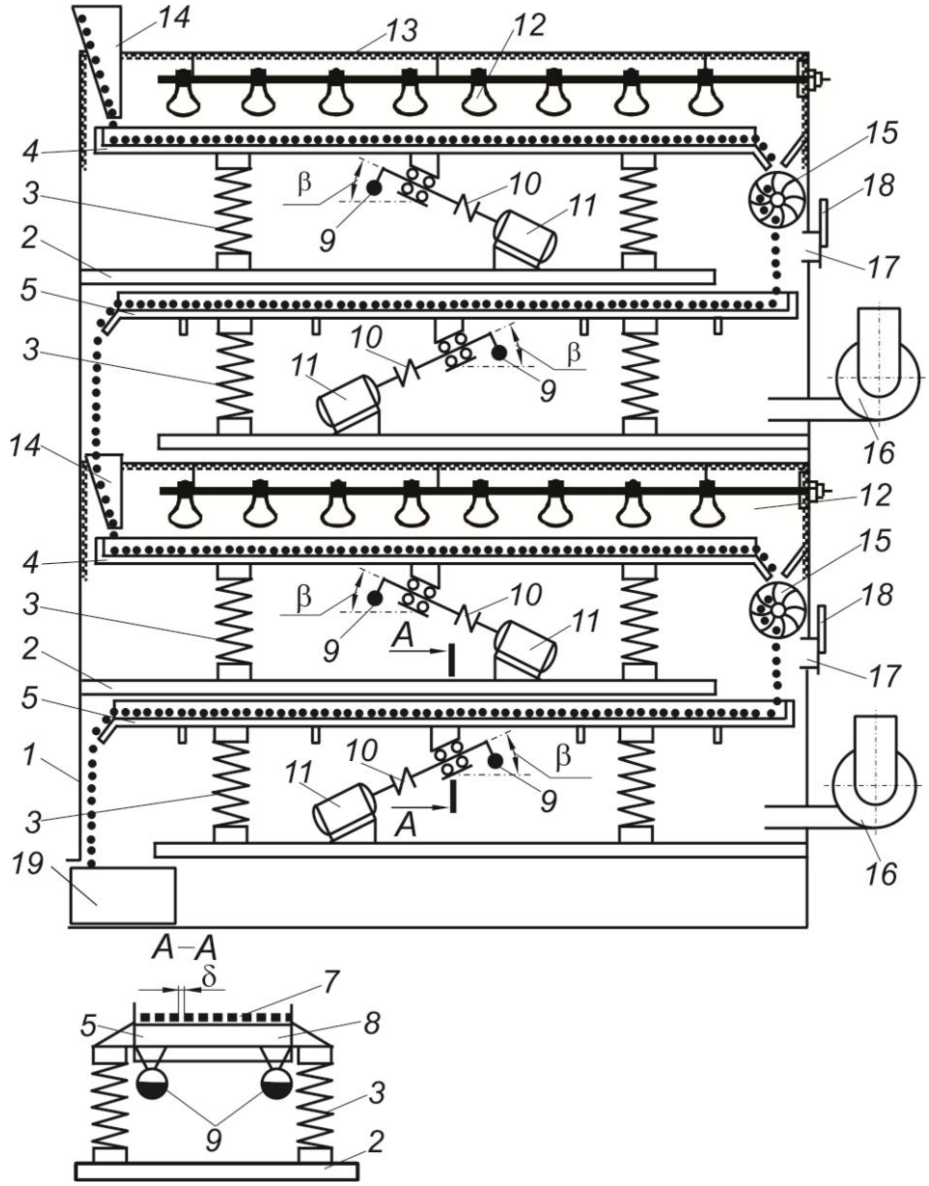

Fig. 6 - Principal scheme of vibration monolayer lot dryer

1 - body; 2 - basic platforms; 3 - springs; 4 - the solid tray; 5 - a grate tray; 7 - strip; 8 - bracket; 9 - shaft with unbalance loads; 10 - elastic coupling; 11 - actuating electric motors; 12 - ICZ lamp; 13 - thermal insulation; 14 - feeding throat; 15 - drum impeller; 16 - electric fan; 17 - branch pipe; 18 - shutters; 19 - the receiving tank.

When the rotors of the activated electric motors *11* start to rotate towards each other in each vibration drive, it leads to a dynamic synchronization of their rotation and results 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 filling throat to the surface of the trays, where the vibrations are distributed by a monolayer. 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 trays. At the same time, the points of the surface of the trays fluctuate relative to some centre 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 throwing of product particles leads to their chaotic whirlabout when moving along thermal trays *4*, over which there are IR heaters *12* and contributes to their uniform irradiation on all sides with infrared rays, which leads to intensive, rapid and uniform heating of sunflower seeds. A reflecting screen is placed on the heater to create a directed beam of radiation from infrared heaters over a layer of grain.

After passing the thermal trays, the heated bulk product is fed through the drum impeller *15* to the grate *5*, which is blown by the atmospheric air from the fans *16*. In this case, the continuous chaotic throwing and turning of the product particles also improves the uniformity of their airflow. It results in a disturbance of the equilibrium state moisture in product particles, when the pressure of water vapour in them becomes greater than the partial pressure of water vapour in the air, as a result of which moisture begins to intensively evaporate. Bulk products alternately pass through several thermal trays *4* and accordingly through several grate stones *5*, which leads to periodic heating and cooling of its particles, and therefore to create optimal conditions for evaporation of moisture, at a low maximum temperature of heating particles of products.

Infrared heaters are installed over a conveyor on which a layer of sunflower seeds (2-3 grains) is placed parallel to the outer surface. A reflective display is placed on the heat layer and the side walls to create a directed beam of radiation from infrared heaters on a layer of grain. Transportation of grain along infrared emitters is accompanied by the mixing of grains normally to the surface of the conveyor, respectively, and before irradiation.

Since the infrared radiation of the thermo-generator *12* can create a very intense heat flux, which facilitates the rapid heating of the particles of products, and the process of evaporation from them requires more time, the speed of vibration transport on the grate bins *5* is set higher, and they are made with wider work paths.

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 products particles heating is 1.5 - 2 times less with larger limits of their humidity. This allows 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 vibrotrays, and therefore the time of their processing on each tray, it is necessary to adjust the parameters of the lot vibrations by changing the magnitude and frequency of force oscillations to provide energy saving resonance mode of vibration drying. To solve this problem, it is possible to use *(Yaroshenko et al. 2018*) or an unbalance controlled vibration drive with an adjustable magnitude of static imbalance, or an unbalance 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 vibrotrays oscillations and to adjust the magnitude of the vibro-exciter force).

CONCLUSIONS

- Complex experimental research was performed in the vibration laboratory infrared monolayer dryer to discover the influence of regime parameters (specific load and power) on the kinetics of sunflower seeds IR drying.
- With an increase in specific power of up to 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 35-43ºC. There was no cracking of the husk.
- Vibration monolayer dry intermittent infrared heating allows reducing the specific energy consumption approximately of up to 1.5-2 times, in comparison with the convection dryer, which retains all the advantages of laboratory infrared monochrome vibration dryer. At the same time, the maximum temperature of products particles heating 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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