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за матеріалами
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ЕНЕРГЕТИКИ ТА ЕКОЛОГІЇ»**

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Розглянуто наступні напрямки досліджень: тепломасообмін; теплофізичні властивості робочих тіл енергетичного обладнання; нанотехнології в холодильній техніці; екологічні проблеми енергетики; теплові насоси. Системи опалення та кондиціонування; теплообмінні апарати; енергетичні та екологічні проблеми нафтогазової галузі; енергетичні та екологічні проблеми холодильної техніки; енергетичні та екологічні проблеми харчової промисловості; екологічна безпека; екологічні проблеми сучасності; раціональне використання природних ресурсів.

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Секція 1:

**«АКТУАЛЬНІ ПРОБЛЕМИ
ЕНЕРГЕТИКИ»**

regenerator. Calculations allow determining the length of the regenerator channels, their number and weight of loaded material, as well as the duration of its effective operation at night for the assigned dimensions of a greenhouse and climatic conditions. The procedure was tested on a greenhouse with an area of 18 m^2 , located in the warm continental climate zone, for April as the basic month for calculations. The method is based on empirical formula (2) to determine the intercomponent heat exchange factor. Calculations showed that the soil generator with 5 channels of square cross-section with the side of 0.4 m must have a length of 5.75 m, which allows placing it along the length of a greenhouse. The weight of rubble makes up 1,265 kg. The amount of accumulated heat $Q_J=46.68 \text{ MJ}$ enables maintaining the temperature in a greenhouse at the level not lower than $16 \text{ }^\circ\text{C}$ for 2.6 hours at the temperature of the environment of $7 \text{ }^\circ\text{C}$. At the higher temperatures of the environment, the duration of regenerator operation in the cooling period will be increased until full compensation of heat losses. The limitation of calculations is that they are of an estimating nature, as the cooling and heating processes in a greenhouse, ambient air, and the layer of material occur in non-stationary modes. The non-stationarity of the processes is taken into consideration by the introduction of average by period air temperatures and granular material. To clarify the procedure, it is possible to include dependences for the calculation of the non-stationary process of heating and cooling separate particles in a layer.

The heat design calculations of the regenerator with the channels of square cross-sections, filled with rubble with equivalent dimensions of particles of 3.5 cm, was performed. It was found that at the average heat flow in day time $Q_c=2,160 \text{ W}$, airflow rate in one channel $G_g=0.066 \text{ kg/s}$, air filtration rate $w_f=0.34 \text{ m/s}$, average intercomponent heat exchange factor $\alpha_{av}=17 \text{ W/(m}^2\text{K)}$, length of the channel $L=5.75 \text{ m}$. The amount of heat accumulated by a layer of rubble is $Q_J=46.68 \text{ MJ}$. For the considered greenhouse with the area of heat transfer surface, $F=70.4 \text{ m}^2$ at an average temperature of the environment at night $t_1=7 \text{ }^\circ\text{C}$ and the average temperature on the greenhouse surface $t_2=16 \text{ }^\circ\text{C}$, accumulated heat can be consumed not less than for $\tau_n=9209 \text{ s}$. At an increase in the temperature of the environment during the regenerator operation, the duration of the regenerator operation will increase.

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THE DRYING OF GRAIN MATERIALS USING A MICROWAVE ELECTROMAGNETIC FIELD

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Thermal treatment of materials of plant origin is determining for the majority of technological processes, specifically, drying, sterilizing and bio-stimulation. The energy crisis and increasing

demand for products with enhanced quality necessitated improvement of traditional technologies and development of the new ones. In this direction, methods that utilize energy of a microwave electromagnetic field (MW EMF) have long proved to be highly effective [1]. Application of microwave heating is considered advisable for the modernization of a range of technological schemes of production [2–5]. However, an incomplete knowledge about effects of a microwave field on plant materials does not make it possible to accept efficient microwave technologies.

Studying the processes of interaction between a microwave electromagnetic field and materials of plant origin, as well as determining treatment conditions, are important objectives for the development of performance-effective and energy-rational technologies.

The aim of present research was to study the effects of a microwave field on the drying. This would enable the creation of new energy-saving and highly-efficient technologies, which would make it possible to exploit the features of microwave energy conversion into internal energy of the material. To achieve the set aim, the following tasks have to be solved:

- to explore the features of the process of drying a layer of grain under different conditions for the removal of evaporated moisture;
- to estimate energy efficiency of converting microwave energy into internal energy of the material.

When studying the drying in a microwave field, we used grains of buckwheat and wheat. The initial moisture content of grain changed from 20 % to 22 %; initial temperature ranged from 17 to 26 °C; weight – from 0.05 up to 1.2 kg; layer thickness ranged from 0.008 to 0.07 m; the surface area of the sample open to remove moisture – from $8 \cdot 10^{-3}$ to $94 \cdot 10^{-3}$ m². Power of the magnetron ranged from 80 to 800 Watts.

Figure 1 shows typical experimental moisture content and temperature dependences on the drying duration in a microwave field at different loading mass.

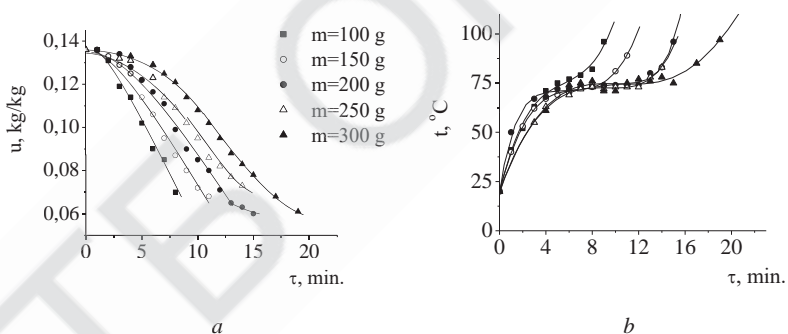


Fig. 1. Kinetics of wheat grain drying in a microwave field at different loading mass: *a* – change in the moisture content; *b* – temperature change

The drying process can be divided into periods, characteristic of colloidal capillary-porous solids at other heat supply techniques: warmup (zero), continuous (first) and falling (second) drying rate. The nature of a temperature change in the first period varied depending on the mass of the load (Fig. 3) and the supplied power. At values of specific power up to $q=450$ W/kg, the temperature remained largely unchanged. With an increase in the specific power, the temperature grew; at values $q>600$ W/kg, its change was essential. The period of the falling drying rate was determined by a change in the moisture content curve: the curve became flat. The temperature always increases over this period. The described pattern was typical for all materials.

Research results showed that the rate of MW drying without overheating the grain is $(0.8\text{--}6.2) \cdot 10^{-4}$ s⁻¹, which is much higher than the values obtained using other techniques of heat supply. Thus, for grain, the conductive drying rate was $0.3 \cdot 10^{-5}$ s⁻¹, that of the conductive-convective – to

$0.2 \cdot 10^{-4} \text{ s}^{-1}$. The possibility to significantly intensify the process testifies to the prospects of applying a microwave field in order to dry the grain crops. Experiments have shown that under the optimal mode the rate of microwave drying with a simultaneous blowing a grain layer with air was $12.7 \cdot 10^{-4} \text{ s}^{-1}$; in this case, specific energy cost per a kilogram of evaporated moisture amounted to 5.65 MJ/kg.

In the process of MW heating of damp grain, overpressure inside the layer starts to rise. The excess pressure at the layer's surface is zero, and it is maximal in the center. A total pressure gradient arises in the layer, which is the driving force of filtration transfer. In order to detect the effect of increasing pressure in the grain layer, we devised the following technique. We placed a container with a layer of buckwheat of height 11 cm in a microwave chamber, and measured excess pressure in the center using a U-shaped kerosene manometer. The choice of kerosene was due to the fact that it did not absorb microwave energy. An exponential increase in the pressure occurred when temperature exceeded 70 °C. In this case, the layer's thickness was 0.1 m. Maximally possible overpressure inside the layer was equal to 640 Pa. When this magnitude was reached, we observed a spontaneous instantaneous pressure relief.

The specificity of microwave heating is in the volumetric character of material's absorption of microwave energy. Microwave energy flux density is maximum in the surface layers, while advancing deep into the material the flow is weakened in line with the exponential law. Therefore, of particular interest for the evaluation of non-uniformity of temperature and moisture content was the kinetics of the layer-wise drying. To this end, we fabricated an experimental cell, which consisted of three layers separated by radiotransparent nets. The weight of each layer was 0.1 kg, thickness was 0.009 m, diameter – 0.135 m, the surface area open to remove steam was $14.3 \cdot 10^{-3} \text{ m}^2$. In the course of the experiment we determined a change in the moisture content and temperature of buckwheat over the drying process for the height of a layer. Only the upper surface of the sample was open to absorb MW energy and remove the steam, with the side and lower surfaces being heat- and moisture insulated. The curves of layer-wise drying kinetics are shown in Fig. 4, which demonstrate that the drying proceeded most intensively in the middle layer. In this experiment, the layer's mass was $m=0.1 \text{ kg}$, thickness $l=0.009 \text{ m}$, $P=160 \text{ W}$. Moisture release rate in the upper layer was somewhat weaker (Fig. 4, *a*). This is related to the fact that the temperature of the upper layer was slightly lower than that of the second (Fig. 4, *b*). Another feature was discovered: the third layer's moisture content increased over time, reaching 0.215 kg/kg (the initial moisture content is 0.2 kg/kg). Therefore, the moisture from the upper layers of the material penetrated down, apparently due to the thermal diffusion mechanism and the force of gravity.

Noteworthy is the following feature – despite the growing moisture content in the bottom layer, that is, an increase in the share of polar dielectric ("receiver" of microwave radiation) in this volume of the material, its temperature remains below temperature of the second and third layers. Experiments on cell, consisting of four layers, showed that the lower (fourth) layer also had the lowest temperature and the highest moisture content, which, as is the case for the previous experiment with three layers, increased over time.

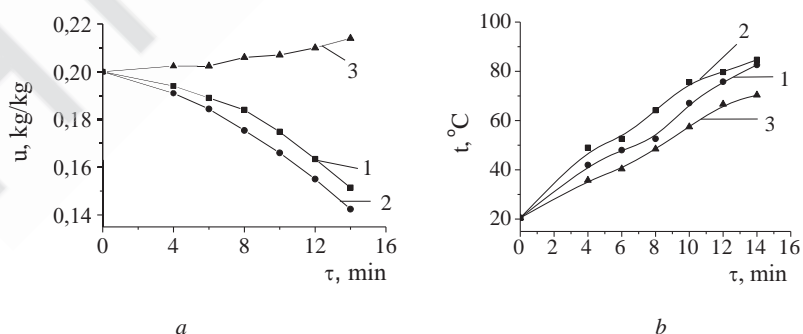


Fig. 2. Kinetics of the layer-wise drying of buckwheat in a microwave field: *a* – change in the moisture content; *b* – temperature change; 1 – upper layer; 2 – middle layer; 3 – bottom layer

Thus, the moisture content of the lower layer increases regardless of the thickness of the sample. The reason for lowering the temperature of the sample at the boundary between the layer and the base of the chamber is the transfer of heat by the conductivity of experimental cell. This irregularity was not observed when using a netted cell that freely passed the steam in all directions. In this case, temperature of the material's layers differed by no more than 4 °C, the humidity – by 0.007 g/kg. Comparing data on the drying kinetics derived at the cell with solid and radiotransparent netted bottom confirmed the importance of rational organization of steam removal. Thus, in the first case the average moisture content of the sample decreased from 0.2 kg/kg to 0.17 kg/kg in 14 minutes, in the second – in 7.5 min. Uneven distribution of temperature and moisture content occurs under conditions when steam removal through the bottom and side surfaces is difficult.

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A MICROWAVE DEVICE FOR THE TREATMENT OF PLANT MATERIALS

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The treatment of plant-based materials is important for the agro-industrial complex. In particular, pre-sowing treatment of seeds is applied to accelerate the appearance of shoots and reduce the plant disease incidence. As a result, the harvest is increased. In traditional technologies, seeds before sowing are warmed, calibrated, soaked in solutions of micronutrients, pelleted, etc. The pre-sowing treatment process is rather lengthy, requires huge material consumption and is not always effective. The pre-sowing seed treatment in the microwave field for biostimulation is simple, energy-efficient and lasts only a few minutes compared to traditional methods. Microwave biostimulation of seeds is associated with an increase in the transport properties of plant tissue due to the development of high-pressure gradients in closed micro volumes of microfibrils of cell walls and pores [1]. The influence on cell walls leads to an increase in the translocation of nutrients and improves seed sowing qualities. Effective use of the voluminous nature of microwave heating can be obtained by preparing a plant substrate for tree-destroying fungi. Plant material after the MW treatment is not only

ТЕПЛОФИЗИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПЛАСТИНЫ МИКРОКАНАЛЬНОГО ТЕПЛООБМЕННИКА С ОТВЕРСТИЯМИ ЖАЛЮЗИЙНОГО ТИПА	
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