INFLUENCE OF TECHNOLOGICAL PARAMETERS OF PSEUDOFLUIDIZED LAYER GRAIN DRYER ON THE GRAIN DRYING QUALITY
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ВЛИЯНИЕ ТЕХНОЛОГИЧЕСКИХ ПАРАМЕТРОВ ЗЕРНОСУШИЛКИ ПСЕВДООЖИЖЕННОГО СЛОЯ НА КАЧЕСТВО СУШКИ ЗЕРНА

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ABSTRACT
We suggest the construction of pseudofluidized layer grain dryer, which allows carrying out grain recirculation inside the dryer with interchange of heating-cooling cycles and providing the possibility to supply drying agent with high temperature into the drying chamber without risking degradation of grain material quality. The dependence of grain heating temperature on drying duration, drying agent temperature and airflow rate are determined. Experimental investigations allowed establishing the rational values of the factors restricting grain overheating beyond maximum permissible temperature.

РЕЗЮМЕ
Предложена конструкция зерносушилки псевдоожиженного слоя, позволяющая осуществить рециркуляцию зерна внутри сушилки с чередованием циклов нагрева-охлаждения и дающая возможность подавать в сушильную камеру агент сушки с высокой температурой без риска ухудшения качества зернового материала. Определены зависимости температуры нагрева зерна от продолжительности сушки, температуры агента сушки и скорости воздушного потока. Экспериментальные исследования позволили установить рациональные значения данных факторов, позволяющие не перегреть зерно выше предельно допустимой температуры.

INTRODUCTION
New dryer construction is suggested. Its technological process is carried out at the account of grain layer pseudofluidization by drying agent.

The investigations to prove technological parameters of drying installation and determine their possible values providing the preset variation limits of wheat seeds temperature and eliminating grain overheating were carried out. To process experimental results we applied experimental statistics. Regression equation is obtained to determine optimal technological parameters of the dryer.

Grain losses and its quality decrease are caused by many factors, including imperfection of dehydration technique. Safety and improvement of technological qualities of harvested grain is achieved, first, by drying. Drying on the account of using scientifically grounded modes, allows increasing efficiency of the process, resistance of stored grain, improving its seed and food qualities *(Tarasenko A.P., 2008; Pilipyuk V.L., 2009; Zhuravlev A.P., 2014)*.

Nowadays in Russia there is the situation of grain being concentrated at agricultural producer while the technical base of its processing is in the possession of other holders. In this situation, the producer has to sell raw material under very unprofitable conditions. Accordingly, creation of small-sized mobile machinery to organize own grain drying at producer is the most promising direction of agricultural enterprise development *(Shhitov S.V., Krivutsa Z.F., Kozlov A.V., 2016; Bibik G.A., 2016; Volkov A.V., 2017)*.

Based on the comparison of the most effective existing methods of grain drying, providing high process rate and small sizes of drying installations of new types "vibrating fluid bed", "falling bed", "suspension bed", "pseudofluidized layer" *(Volzhentsev A.V., 2014; Kalashnikova N.V. u Volzhentsev A.V., 2009; Kuznetsov Y.A., Volzhentsev A.V., Kolomeichenko A.V., Kalashnikova L.V., 2017)*, it is possible to stress that the utilization of "pseudofluidized layer" type installations prove maximum potential to increase efficiency and intensity of drying process.

MATERIALS AND METHODS

General view and basic constructional units of the developed experimental drying installation are presented in figures 1 and 2.

Alteration and control of the basic parameters of the drying installation were carried out in the following way:

– the air flow pressure adjustment at inlet and outlet from grain layer was provided by alteration of flow section of forced-draught fan VL14-46-2,5-01A. Pressure control is done by digital differential pressure gauge DMT-01M;

– the air flow rate in drying chamber was measured by digital differential pressure gauge DMT-01M. However, the flow rate of drying agent was determined at 9 points: at 6 points along drying chamber walls and at 3 points along symmetry axis of functional area, stretching from loading hole to outlet louver;

Fig. 1 – General view of pseudofluidized layer experimental dryer

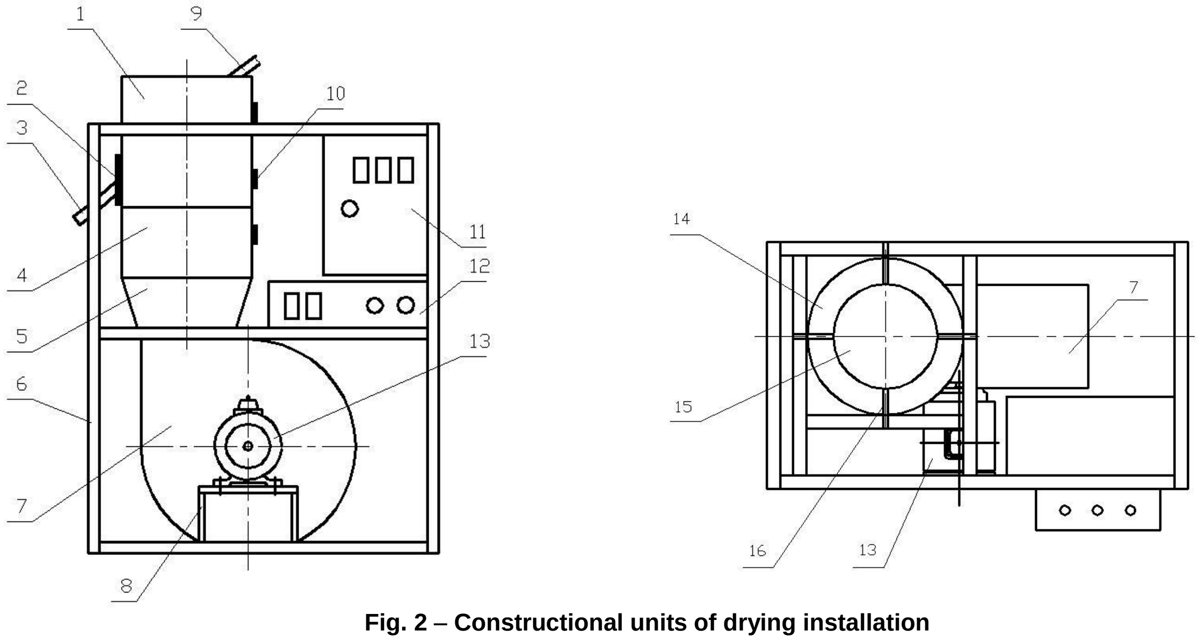

Fig. 2 – **Constructional units of drying installation**

1 – working chamber; 2 – slider; 3 – unloading sleeve; 4 – electric heater; 5 – diffuser; 6 – frame; 7 – fan; 8 – electric engine frame; 9 – loading sleeve; 10 – plug of technological hole for measurements; 11 – console unit; 12 – measuring instruments; 13 - electric engine; 14 – cooling chamber; 15 – drying chamber; 16 - holder

– the temperature of drying agent in lower turning joint and in drying chamber was controlled according to the data of digital differential pressure gauge DMD-01M. The necessary drying agent temperature was provided with periodical switching off one or more sections of electric heater.

RESULTS

Technological process of experimental dryer operation proved that the main factors determining grain drying quality are drying agent temperature and drying time.

The investigations were carried out to ground technological parameters of drying installation and determining their possible values providing the specified limits of seed wheat temperature variations and eliminating grain overheating. In this regard, it was necessary to study the temperature changes of drying agent t and drying time $B_{drying.}$ in the heating temperature T of pseudofluidized grain layer.

Drying agent temperature t, ^0C was selected with the following values: 60; 80; 100. Temperature variation was done by means of switching on and switching off additional sections of electric heater. Drying time $B_{drying.}$, *sec* was admitted equal to 100; 200; 300; 400; 500; 600.

The experimental results studying the influence of the mentioned factors on temperature and humidity of pseudofluidized layer of grain material are presented in figures 3, 4, 5.

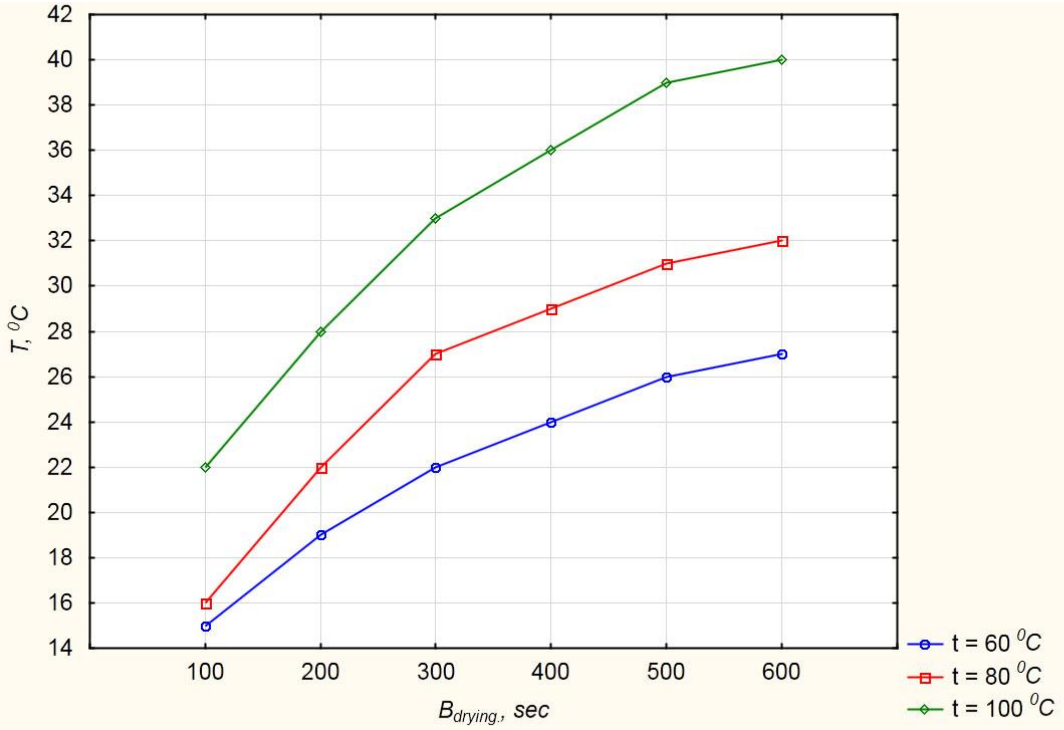

Fig. 3 – Dependence of grain temperature *T* on drying time $B_{drying.}$ at different values of drying agent temperature *t*

Analyzing the obtained dependences of grain temperature (fig. 3) on drying time $B_{drying.}$ at different values of drying agent temperature t, it is possible to conclude that at drying time increase, grain temperature increases and at the end of time limit it does not exceed maximum permitted time. With increase of drying agent temperature grain heating process is intensified sharply and at the meaning of t = 100^{0}C grain temperature T reaches critical value.

Characteristic curves analysis of grain temperature T from drying agent temperature t (fig. 4) displays that with the increase of drying agent temperature, grain temperature increases and reaches ultimate and maximum permitted value at t= 100 ^{0}C.

Grain heating intensity depends also on air flow rate (filtering rate) v penetrating pseudofluidized grain layer. Minimum operating air rate providing sustainable and even layer boiling was admitted equal to 2.2 m/sec. Maximum filtering rate value was 3 m/sec. Further rate increase was inappropriate because it results in non-productive losses of drying agent.

Characteristic curves analysis of grain temperature T from filtering rate v (fig. 5), at different temperatures of drying agent t shows that the process grain heating is significantly intensified with rate growth *v*. Grain temperature *T* reaches its maximum value at drying agent temperature equal to 100^{0}C and air flow rate about 3 m/sec.

Further rate growth *v* results in overheating and grain technological properties decreasing.

To estimate the effect of the interaction of technological and operating parameters of the experimental dryer on the grain material temperature full factorial experiment was carried out. The regression equation of the following type was obtained:

$$T = 47,729 - 0,899t + 0,0033B_{drying.} - 8,624v + 0,0045t^2 - 0,00004B^2_{drying.} + 0,1423tv + 0,0003tB_{drying.} + 0,0122B_{drying.}v \quad (1)$$

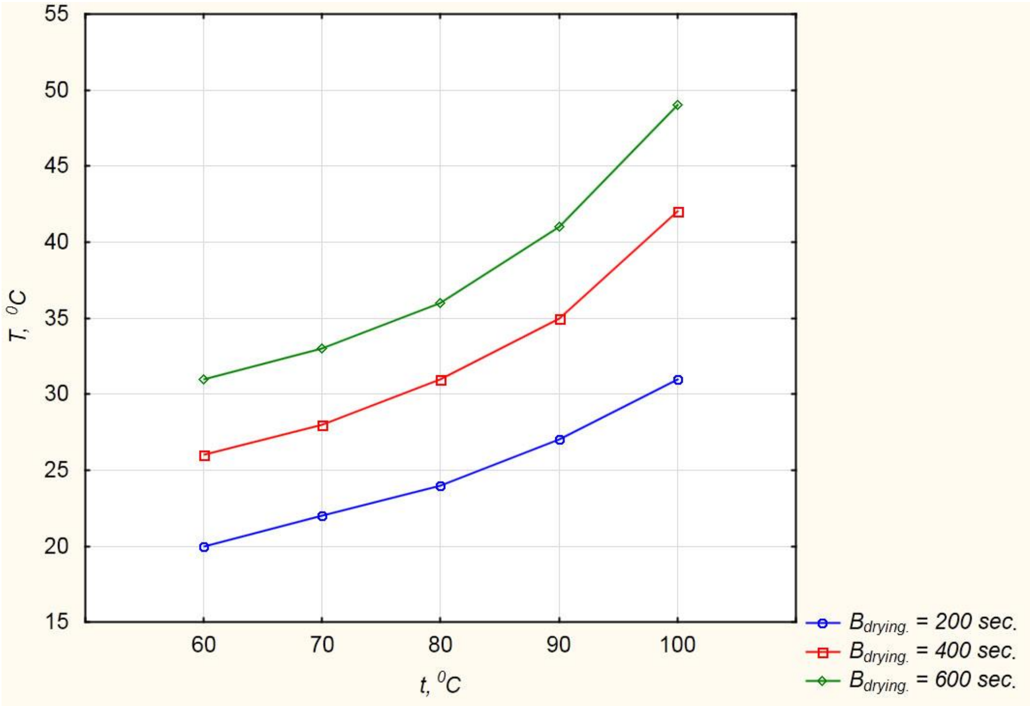

Fig. 4 – Dependence of grain temperature *T* on drying agent temperature *t* at different values of drying time $B_{drying.}$

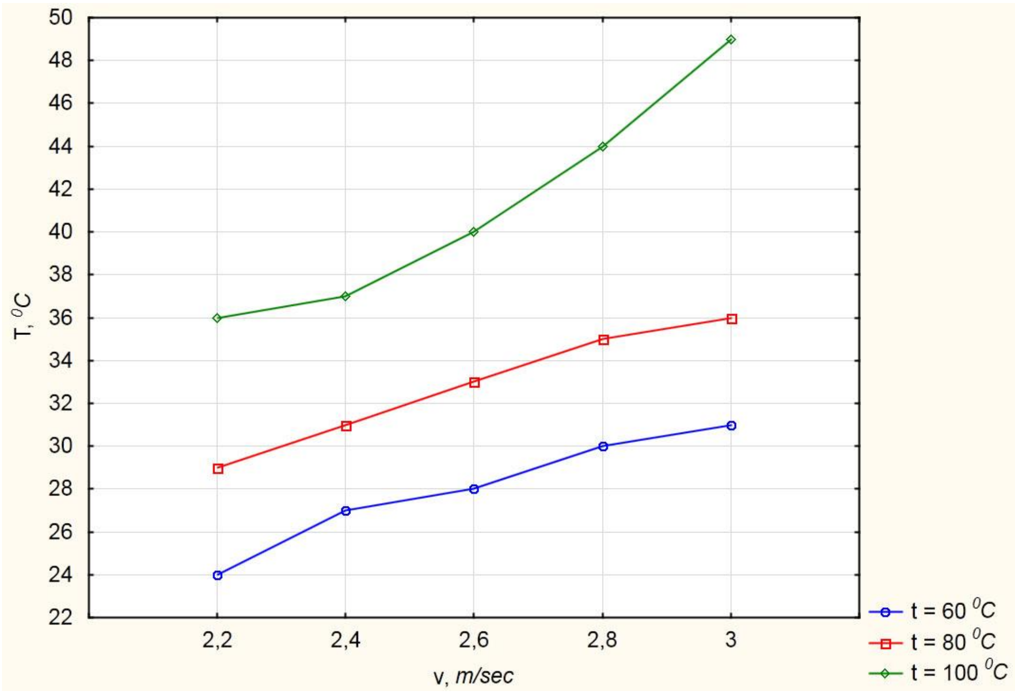

Fig. 2 – Dependence of grain temperature *T* on filtering rate *v*

After substitution of the corresponding values of the main factors, factorial dependence of temperature variations of grain *T* in grain dryer is drawn (fig. 6).

Graphical interpretation analysis of the obtained data suggests that grain heating temperature increases with increase of temperature and drying agent rate. However their marginal values correspond to the following values: t = 100^{0}C, v = 3 m/sec. Maximum drying time at different values is 600 sec. Further increase of the concerned factors is unreasonable, because it will result in grain overheating and its quality deterioration. The experimental dryer due to grain recirculation with oscillation mode permits to prevent overheating of grain material at the expense of heating-cooling cycles interchange. Grain, moving along the complex path, gets into the lower part of the layer, into the active heat exchange area, and receives some heat. Grain, pushed up by airflow, gets into the upper part of the layer where it loses part of the accumulated heat, after touching the colder surface of other grains. As a result, the grain temperature, which is gained at the lower part of the layer, decreases to the moment of getting into the active heat exchange area and receiving another heat impulse. A separate grain temperature increases non-linearly along some wave curve, when maximums are interchanged with minimums, but maximums increase gradually. At the developed boiling, regardless the layer elevation, uniform grain heating is provided and the temperature of the used dryer agent is practically equal to zero.

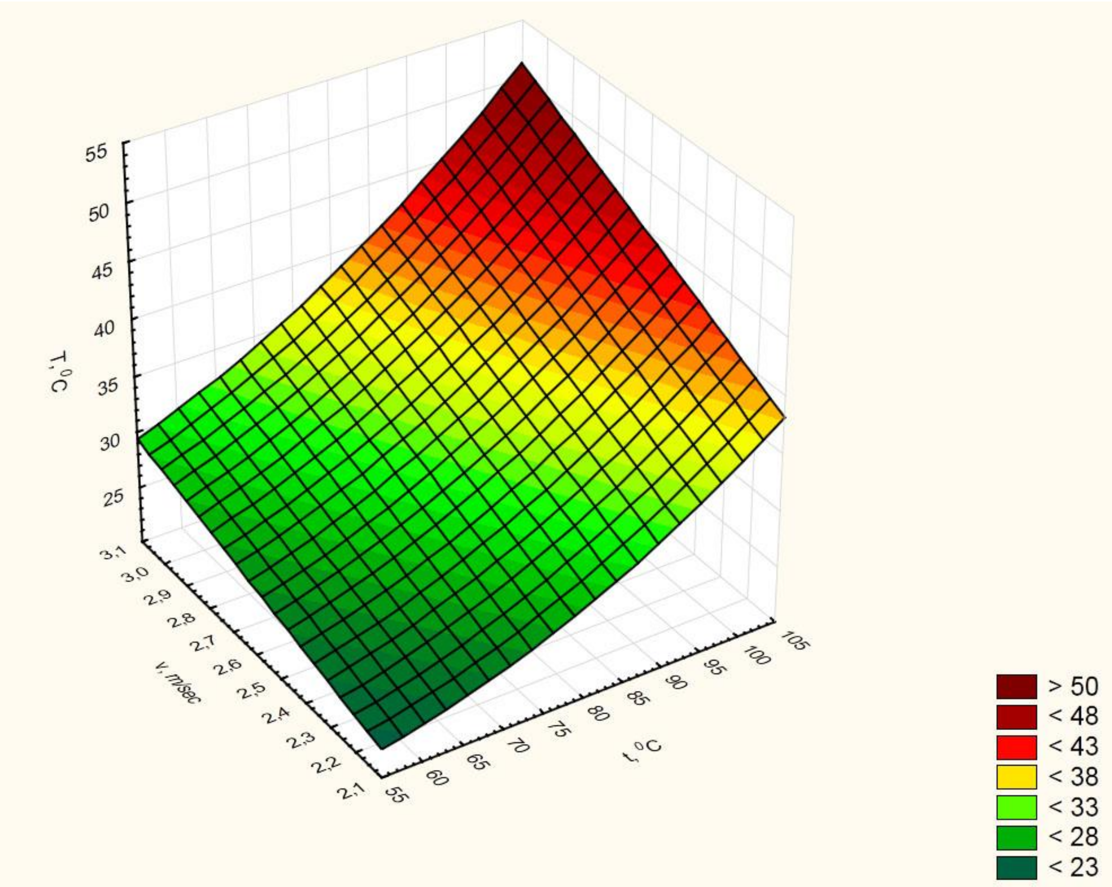

Fig. 6 – Factorial dependence of temperature grain heating within experimental dryer

CONCLUSIONS

1. On the ground of the laboratory research practical guidelines to manufacture are developed: at grain drying in pseudofluidized layer it is recommended to use drying agent with temperature up to 100^{0}C. Further increase of air flow temperature at seed drying for food and especially of seed designation is unreasonable because it will result in grain material overheating.

2. While designing grain dryers of pseudofluidized layer we should limit ourselves with the range of drying agent rates from 2.2 to 3 m/sec. Maximum drying duration to grain material overheating is 600 sec.

3. The developed dryer utilization provides to decrease power demand by over 20% in comparison with serial constructions of small-scale dryers.

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Agrarian University named after N.V. Parakhin" (Russian Federation). The tests provided drying up to normal amount of moisture and cleaning from light impurities of grain-thrashed heap. The tests were carried out at the place of postharvest treatment of grain material. On completing, the technological process of drying, at unloading grain from dryer, caryopses with changed colour or flavour as the evidence of their damage were not detected. The usage of the developed dryer allowed high quality grain drying after its harvesting, at drying installation efficiency of 180...250 kg/h.

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