RESEARCH ON THE RATIONAL REGIMES OF WHEAT SEEDS DRYING
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ДОСЛІДЖЕННЯ РАЦІОНАЛЬНИХ РЕЖИМІВ СУШІННЯ НАСІННЯ ПШЕНИЦІ

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ABSTRACT
The value of the grain seeds is in the ability to germinate and ensure high yields. The main technological process for preserving the properties of seeds is drying. The proper carrying out and providing of rational modes of drying is a necessary condition to preserve the high ability to germinate. For the object of drying we have taken wheat seeds to determine the rational regimes. The research of the drying process kinetics is carried out on a convective drying stand in the following modes: coolant temperature in the drying chamber t = 50-80˚C, velocity V = 0.5-1.5 m/s. The highest intensity of drying occurs from an increase in the temperature of the coolant from 50 to 80°C in 3 times, but the main indicator is wheat maximum permissible temperature, which, at the coolant temperature of 50°C, is 48.6°C.

The biochemical indicators of wheat seeds were determined in the laboratory of the Institute of Technical Thermophysics according to the method on the 7th day of germination. The results of the researches showed that the best results of wheat germination were at 50°C at the level of 96%. Coolant temperature of 80°C has the most negative influence on wheat germination as the seeds lose their properties.

The analysis of the three-factors of influence, such as temperature and speed of coolant, as well as wheat initial humidity, on seed drying time and germination is done.

The obtained regression equations and obtained response surfaces of seed drying time and germination enable us to evaluate the process in terms of drying parameters' influence.

РЕЗЮМЕ
Цінність насіння зернових культур полягає у здатності пророщування та забезпечення високого врожаю. Основним технологічним процесом для збереження властивостей насіння є сушіння. Правильне проведення і забезпечення раціональних режимів сушіння є необхідною умовою збереження високої здатності до проростання. Для визначення раціональних режимів за об'єкт сушіння нами взято насіння пшениці. Дослідження кінетики процесу сушіння проведені на конвективному сушильному стенді за таких режимів: температура теплоносія в сушильній камері t = 50-80˚C, швидкість руху V = 0,5-1,5 м/с. Найбільша інтенсивність сушіння відбувається від збільшення температури теплоносія від 50 до 80ºС в 3 рази, але основним показником є гранично-допустима температура пшениці, що при температурі теплоносія 50°C складає 48,6°C.

Біохімічні показники насіння пшениці визначались в лабораторії Інституту технічної теплофізики за методикою на 7 день пророщування. Результати досліджень показали, що найкращі результати пророщування пшениці при 50°C на рівні 96%. Найбільш негативно впливає на схожість пшениці температура теплоносія 80°C і насіння втрачає свої насіннєві властивості.

Проведений аналіз трифакторного впливу параметрів сушіння – температури та швидкості руху теплоносія, а також початкової вологості пшениці на тривалість сушіння та схожість насіння. Отримані регресійні рівняння та отримані поверхні відгуку тривалості сушіння та схожості насіння, дають можливість оцінити процес від впливу параметрів сушіння.

INTRODUCTION
The problem of drying wheat seeds has been raised by various authors and it requires the choice of the most rational drying regime. Different approaches and different technological equipment may not always accurately reflect the choice of the desired drying regime. The elevated temperatures of the coolant during wheat seeds drying are given in works (*Kovalenko O.A., Kosovska N.V., 2012; Savchenko S.V., 2009*)

associated with the conditions of passing the grain through the drying chamber of the shaft dryer, where additionally the following drying factors are added: the velocity of the coolant and grain, the height of the grain layer, the hydraulic resistance of the layer, constructive features and other conditions. Under laboratory conditions, when drying in the elementary layer (*Matkivska I.Ja., Atamanyuk V. M., Symak D., 2014*), drying modes can be characterized more adequately and reliably, but there is a problem with the transfer of research results to industrial installations. The main criterion for evaluating seed grain quality is wheat heating temperature, which is determined by seed germination ability.

To determine wheat seeds germination, the author has proposed to dry the wheat seeds from 80 to 120°C and step modes with an increase in temperature of 80/100 and 80/120°C (*Podpryatov G.I., Nasikovsky V.A., 2005*). There is no indication of the effect of these drying conditions on wheat seed properties, only the storage modes are mentioned. In particular, it is indicated that wheat seeds should be stored during the first month with a moisture content of 18.0-18.5%, thus increasing the ability to germinate.

Similar modes of drying are represented in the research work of Kovalenko O.A. for drying wheat at 80 - 120°C and stepwise drying mode at 80/100 and 80/120°C. The presented studies show that at the temperature of 80°C the germination is 89-94,5%, while in stepwise mode it is 63-81%, which cannot be recommended for seed grain at all (*Kovalenko O.A., Kosovska N.V., 2012*).

In the work of Savchenko S.V. the drying of wheat seeds was carried out in a gravitational-moving layer at the temperature of the heat carrier 70 - 85ºC, and at the same time the temperature of heating the grain was 50 - 62ºC (*Savchenko S.V., 2009*). The greatest germination of wheat seeds at the temperature of 70°C is 90%, and at an increase of temperature it is 85 - 83%.

In the research work of Matkivska V., the conditions of wheat seeds drying from 40 to 80 ºC were analyzed. The germination at a drying temperature of 40, 50, 60, 80ºC, respectively, is 99, 98, 90, 30%. In this case, it is recommended to use the temperature of 60°C, although it would be desirable to choose a temperature of 50°C according to the results of the experiment (*Matkivska I.Ja., Atamanyuk V. M., Symak D., 2014*).

MATERIALS AND METHODS

The high cost of seed grain and energy has set the task for us: to pick up such drying regimes, that can provide the high quality of seeds, while minimizing the specific heat consumption of the process.

Describing the processes of grain drying, they can be conditionally divided into soft and rigid drying regimes. The first one is characterized by a relatively low temperature and drying agent speed. In a soft mode, the processes of heating and drying the grain pass with a relatively low speed. The rigid mode is characterized by increased temperature and speed of the drying agent. From the economic point of view, it is desirable to dry the grain in rigid mode with a decrease in the drying time. However, in rigid mode due to intense heating and dehydration there is deterioration in its quality: cracking of seeds, change in colour, partial or complete destruction of the embryo, deformation of tissues.

The application of high temperatures at the beginning of wet grain drying process leads to a rapid dehydration of its surface, which makes the shells less permeable to moisture (the phenomenon of thermal "quenching" of the grain). Under these conditions, a water vapour forms in the surface layer, the output of which becomes complicated. It is therefore recommended to dry the seeds at relatively soft temperature regimes. In soft mode, drying does not have a complete guarantee of preservation of seed grain properties, so during prolonged low temperature drying (depending on the environmental parameters) the formation of mould on the surface is possible, and as a result, the damage of the seed material.

The main parameters that determine the choice of the drying mode and the achievement of high quality indicators of dried seeds are the temperature of the drying agent, the grain heating maximum temperature, the seeds initial humidity and the duration of their drying. The initial moisture content of grain ω_0 greatly affects the intensity of the drying process and determines the choice of the maximum allowable temperatures for heating the grain and the maximum temperatures of the drying agent.

The maximum permissible temperature for the grain intended for seed is determined based on the conditions of energy storage of its germination capacity. With the increase in humidity and the duration of grain presence in the heated state, the maximum allowable temperature of it is reduced.

The works of S.D. Ptitsina, M. Hutchson, V.I. Zhidko, O.N. Katkova, V.A. Rezchikov, N.N. Nevsky, V.L. Prokofiev, K.S. Esbolganov are dedicated to the determination of the maximum allowable temperature of heating the grain (table 1).

Finding the maximum-permissible temperature of seed grain in the proposed formulas of S.D. Ptitsina and M. Hutchison depends on the initial humidity and the time of heating the grain *t*.

V.I. Zhidko determined the maximum allowable temperature of the grain heating by introducing the coefficients and values of the heating time *t, n, k* and the grain moisture content *ω*.

O.N. Katkova, V.A.Rezchikov on the basis of processing the experimental data proposed the empirical formula, depending on the mass air velocity *Vρ*, which characterizes the state of the layer (on which the drying time depends), the humidity ω and the initial temperature of the coolant *t*.

N.N. Nevskaya and V.L. Prokofiev, based on the mass spectrometric radiation of wheat drying features, proposed the dependence of the maximum permissible grain temperature on the humidity *ω* and the drying time *t.*

K.S. Esbolganov, under the conditions of recirculation drying, proposed to use grain mass concentration in the heating chamber *μ*, the temperature of the coolant *t* and the value of the moisture content ω_c to calculate the maximum permissible temperature of heating wheat seeds.

Table 1

The equation for determining the maximum permissible temperatures for heating the seeds

№	Researcher	Equation	№ Eq.	Source
1	*S.D. Ptitsin*	$\theta_{ГР} = \frac{2350}{0{,}37(100-\omega_0)+\omega_0} + 20 - 10\lg\tau,$ where: ω_0 - initial humidity of grain,%; τ - time of grain heating, min.	(1)	*(Melnik B.E., Malin N.I., 1980)*
2	*M. Hutchinson*	$\theta_{ГР}$ = 122,0 – 5,41lgτ - 441 lgω_0, where: ω_0 - initial humidity of grain,%; τ - time of grain heating, min.	(2)	*(Shchitsov S.V., Tikhonchuk P.V., Krivuta Z.F., Kolzov A.V. 2016; Shchitov S.V., Krivueca Z.F., 2012)*
3	*V.I. Zhidko*	$\theta_{ГР} = t_0 - n \cdot \omega_0 + k$, where: t_0, n are the constant coefficients obtained experimentally for grain with normal gluten $t_0 = 88$, $n = -2{,}15$; *k* – coefficient depending on the duration of drying τ and moisture content of the grain: $k = 0{,}03\omega_c^2 - \frac{\tau - 90}{0{,}023\omega_c^2}$ where: ω_c - current moisture content of grain,%; τ - time of grain heating, min.	(3) (4)	*(Zhidko V.I., Atanazevich V.I., 1982)*
4	*V.A. Rezchikov, R.P. Dubinicheva*	$\theta_{ГР} = 1800\frac{(V\rho)^{0{,}13}}{\sqrt{\omega}t^{0{,}4}}$ where: *Vρ* - mass velocity of air, kg/m^2; *ω* - grain moisture content,%; *t* - coolant temperature, °C	(5)	*(Rezchikov V.A., Dubinicheva R.P., 1988)*
5	*N.N. Nevsky, V.L. Prokofiev*	$\theta_{ГР} = \frac{900 + 273\omega + \omega^2}{\omega} - 10\lg\tau,$ where: *ω* - grain moisture content,%; τ - time of grain heating, min.	(6)	*(Tits Z.L., 1967)*

It is most appropriate to determine the drying regime according to the biological properties of the grain. Acceptable values of temperatures at different time values of impact on the grains, which does not affect the processes of life in it, depend on the moisture content of the grain – the higher the humidity, the lower the permissible values of temperatures.

An irreversible decrease of wet grain lifetime begins at 55°C (coagulation of protein in the germ and aleuronic layer), and of dry grain at 65°C. During drying it is necessary to reduce the final temperature of heating of seeds by 10-12C, which will allow to preserve the seed properties of the material (fig. 1). (*The results of the investigation of physical processes during the drying of grain, 2018*).

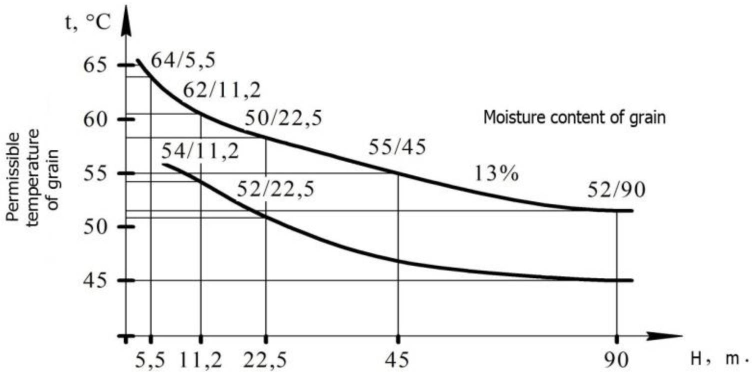


Fig. 1 - Change grain permissible temperature during drying for different humidity of seed grain

It is necessary to apply a milder drying regime for seed grain. According to M.G. Golik, a complete loss of wheat seeds germination occurs when heated to 60°C, at initial moisture content of 20% and higher. The germination of unprocessed seeds at a humidity of 20% was 97%, when heated to 45, 50 and 55°C, the germination was 87, 82 and 47% respectively. The intensity of moisture removal, which should not exceed 5%, was indicated in the work. (*Golik M.G., Delidovich V.N., Miller B.E., 1972*).

In the work of Savchenko, the studies on the germination of wheat seeds differ significantly from the data presented by M.G. Golik. Experimental studies are carried out at the temperature of 75, 85°C, respectively, heating the grain up to 50.56°C with a germinating capacity of 90 and 85% respectively (*Savchenko S.V., 2009*).

The temperature change of the grain and the reduction of the material mass were determined using special devices and the developed program in an automatic mode on a convective drying stand. In order to assess the quality of the wheat seeds, the standard methods of research were provided by SS 4138 - 2002 and SS 2240 - 1993 (State Standard 4138 - 2002, 2003; State Standard 2240 - 1993, 1994).

The research program involves removing the wheat drying kinetics by recording the changes in the mass of the material, temperatures of the coolant and in the middle of the material (fig. 2).

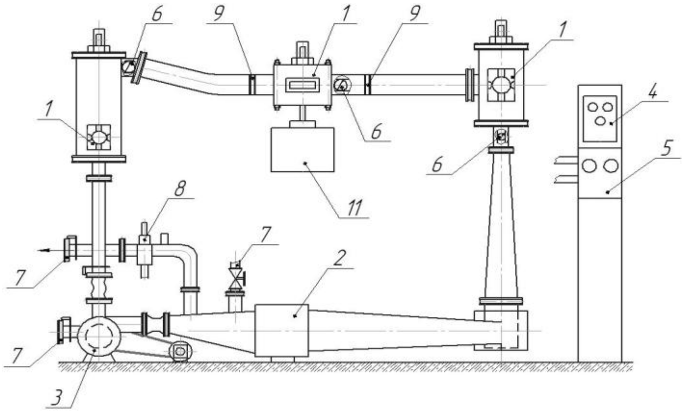


Fig. 2 - Scheme of the experimental stand:

1 - drying chamber; 2 - heater; 3 - fan; 4 - temperature controller; 5 - control panel; 6 - thermometers; 7 - pipe fittings; 8 - psychrometer; 9 - special gratings; 10 - a bar of scales; 11 – scales

RESULTS

An example of removing the kinetics of the wheat seed drying process at a coolant temperature of 50°C and a flow velocity of a coolant of 0.5 m/s is shown in fig. 3

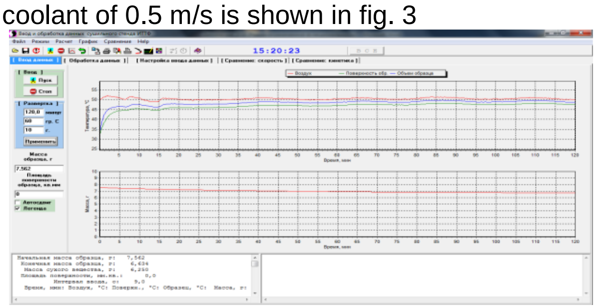


Fig. 3 - Removal of kinetics of wheat drying at the coolant temperature of 50°C and the speed of 0.5 m/s

The main direction of the intensification of wheat seeds drying process is coolant temperature; the higher the temperature, the drying rate increases (fig. 4).

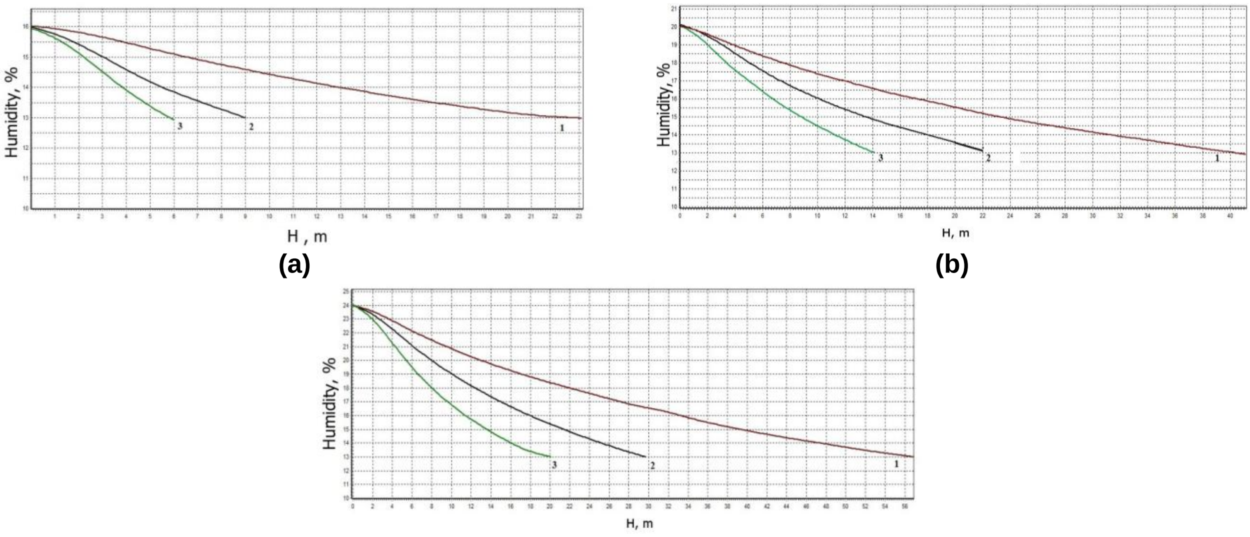


Fig. 4 - Curves of wheat seed drying depending on the coolant temperature,
at initial humidity of material 16 (a), 20 (b), 24 (c), 1.5 m/s
1 - 50°C; 2 - 65°C; 3 - 80°C

The increase of the coolant temperature accelerates the drying process, so at a temperature of 80°C compared with 50°C, the wheat drying is faster by almost 3 times. The initial moisture content of the material increases the drying time, so the duration at a moisture content of 24% to the final moisture of 13% is 57 minutes, and a decrease of moisture up to 20% reduces the duration of the process by 16 minutes.

On the presented temperature curves of wheat seeds heating it can be seen that the material is most rapidly heated for 6 - 8 minutes, and then there is a gradual heating to the final temperature (fig. 5). So the final temperature is: at 50°C - 48,6°C; 65°C – 62,26°C; 80°C - 74,62°C.

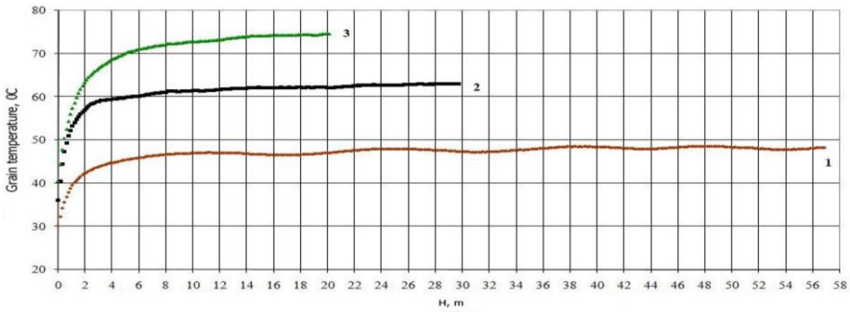


Fig. 5 - Temperature of wheat seeds heating during drying period
at initial humidity of material 16 (a), 20 (b), 24 (c), 1.5 m/s
1 - 50°C; 2 - 65°C; 3 - 80°C

Wheat seeds drying rate, depending on the coolant temperature, is shown in fig. 6. When wheat seeds are dried, there is a period of warming up of the material and a period of falling drying rate. In the period of warming, the material is heated and a partial evaporation of the moisture from the surface layers takes place.

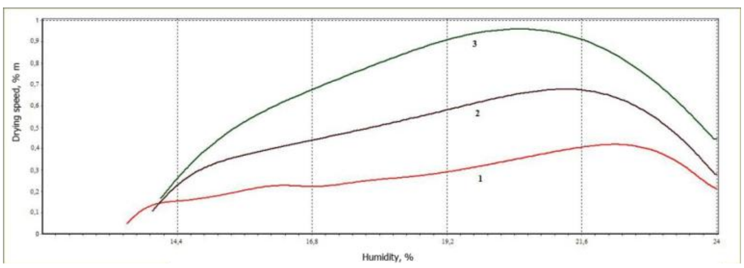


Fig. 6. Curves of wheat drying rate at an initial humidity of 24% and
coolant speed 1.5 m/s from temperature
1 - 50°C; 2 - 65°C; 3 - 80°C

The maximum drying speed at a temperature of 80°C is 0.95%/min., the decrease to 65°C reduces the speed up to 0,67%/min, and when reduced to 50°C, it is 0,41%/min.

The curves of wheat seed drying from the effect of the heat transfer velocity showed that with an increase in the velocity of the coolant from 0.5 to 1.5 m/s, the increase in the drying rate is 7.3%. Drying occurs to the final moisture content of wheat 13%, which corresponds to the equilibrium moisture content of the material (fig. 7).

Fig. 8 shows the curves of the drying speed at different coolant flow velocities, so at coolant velocity of 1.5 m/s the maximum drying speed at 18.6% humidity corresponds to 0.3%/min. At coolant flow velocity of 0.5 m/s, the drying rate is reduced up to 0.25%/min, namely by 20%.

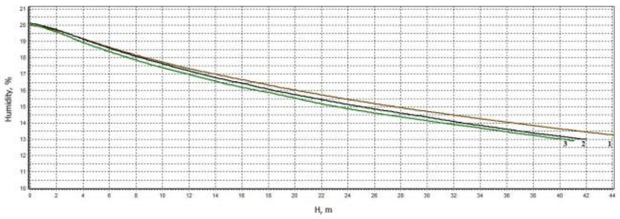


Fig. 7 - Curves of wheat seed drying at coolant flow velocity and a temperature of 50°C
1 – 0,5 m/s; 2 – 1,0 m/s; 3 – 1,5 m/s

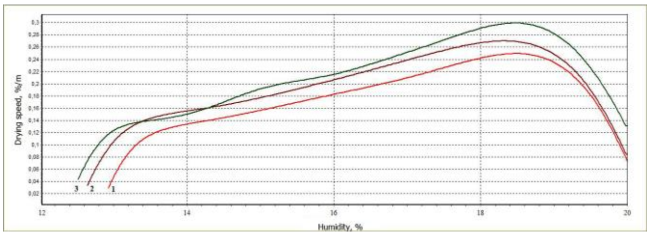


Fig. 8 - Curves of drying rate of wheat seeds from the coolant flow velocity at the temperature of 50°C
1 – 0,5 m/s; 2 – 1,0 m/s; 3 – 1,5 m/s

The rational drying regime was determined by the biochemical properties of wheat seeds, depending on the temperature, the initial humidity and the coolant flow velocity (table 2).

Table 2

The influence of drying parameters on wheat germinating capacity on the 7-th day of germination

Temperature of the drying agent, ºC	Initial moisture content of grain,%	Drying agent speed, m/s	Seed germination,%
Output	-	-	99
50	16	1.5	96
50	20	0.5	96
50	24	1.5	96
65	16	1.5	94
65	20	0.5	93
65	24	1.5	90
80	16	1.5	1
80	20	0.5	9
80	24	1.5	0

From the data given in tab. 2, we can draw a conclusion about the significant influence of these parameters in the area of high temperatures. Rational drying mode is the temperature of 50°C, where the influence of the initial moisture and the speed of the drying agent are not significant.

The graphs of the drying parameters' influence on wheat germinating capacity on the seventh day of germination are shown in figure 9.

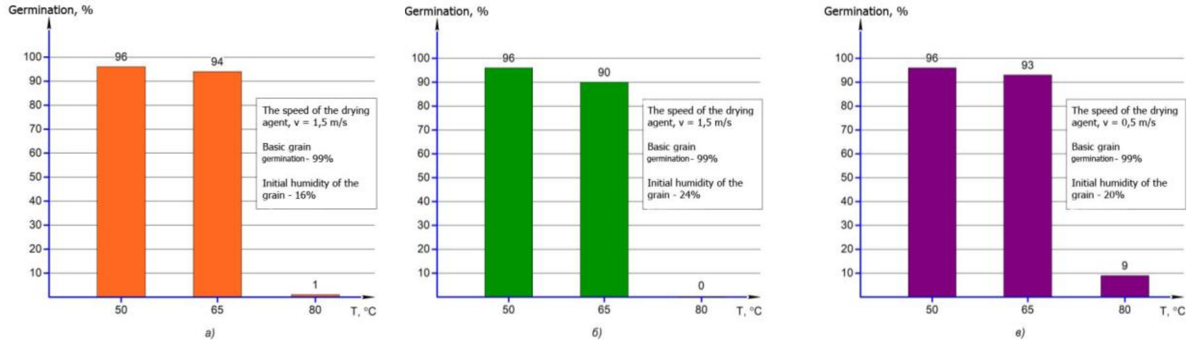
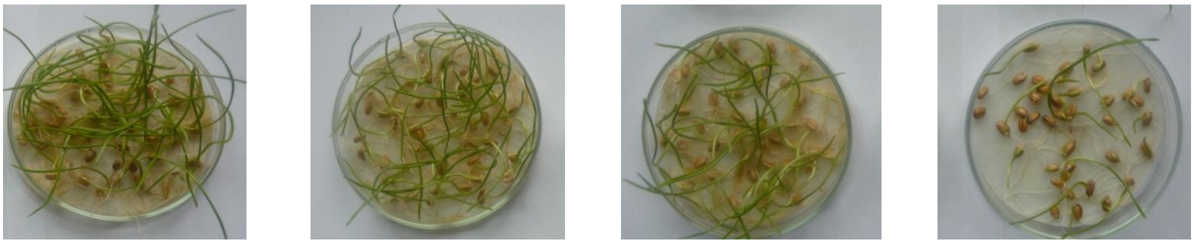


Fig. 9 – The effect of drying parameters on wheat germinating capacity on the 7-th day of germination

We can assess visually the influence of the coolant temperature on the presented fig. 10.



Output 50 65 80

Fig. 10 – The influence of coolant temperature on the germinating capacity of wheat seeds on the 7-th day of germination at the initial moisture content of 20% and the speed of 0.5 m/s

For a mathematical description of the wheat drying process in an elementary layer, we take a three-factor experiment in accordance with an orthogonal compositional plan of the second order.

The total number of points in the plan is determined by:

$$N = 2^n + 2n + N_0; \tag{1}$$

where: $N_1 = 2^n$ - number of points of the factor space, determined by the core of the plan. For a three-factor experiment n = 3, that is $N_1 = 2^3 = 8$

$N_2 = 2n = 6$ - the number of stellar points;

$N_0 = 1$ is the number of central (zero) points of the plan.

So, holding a three-factor experiment on three levels requires the conducting of 27 experiments.

That's why it is necessary to establish the optimal amount of experiments required. This task can be solved using modern methods of planning an experiment, in particular mathematical, the basis of which is the creation of a mathematical model in the form of a regression equation.

In orthogonal central planning, the criterion for optimality of the experiment plan is the orthogonality of the planning matrix columns. Because of the planning orthogonality, all the coefficients of the regression equation are determined independently of each other. The core of the composite plan is the plan for a complete factor experiment CFE 2^n.

Experiment planning included the following steps:

– compilation of the coding table of factors and levels of variation;

– drawing up a plan - matrix;

– conducting the experiments according to the plan-matrix

– compilation of the regression equation and definition of the coefficients of the equation;

– analysis of the mathematical model in the form of a regression equation.

In the first stage we will compile a table of factors and levels based on the results of the research on a convective drying stand (table 3):

Table 3

Factors and levels of variation, that influence the wheat seed drying process

Indexes	**Factors**		
	Heat carrier		**Material**
	Temperature t, ºC	***Speed V, m/s***	***Initial humidity W_0, %***
Top (+1)	80	1.5	24
Average (0)	65	1.0	20
Lower (-1)	50	0.5	16
Variable interval	15	0.45	4
Code mark	x_1	x_2	x_3

According to the plan, the research was conducted using three levels for each factor - upper (+1), zero (0) and lower (-1), the code values of which were determined by the formula:

$$x_1 = \frac{t - t_0}{\varepsilon_1} = \frac{t - 65}{15}; \qquad x_2 = \frac{V - V_0}{\varepsilon_2} = \frac{V - 1{,}0}{0{,}5}; \qquad x_3 = \frac{W - W_0}{\varepsilon_3} = \frac{W - 20}{4}, \tag{2}$$

where: t_o, v_o, w_o – the value of the factors at the main level, respectively, the temperature and velocity of the coolant, the initial humidity and the height of the canola layer;

ε_1, ε_2, ε_3 – the interval of factors variation.

The mathematical models of the process were constructed in the form of regression equations:

$$\overset{\frown}{y} = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_{11} x_1^2 + a_{22} x_2^2 + a_{33} x_3^2 + \\ + a_{12} x_1 x_2 + a_{13} x_1 x_3 + a_{23} x_2 x_3. \tag{3}$$

The coefficients of regression can be determined by the following formulas:

$$a_0 = \frac{1}{N}\sum_{k=1}^{N} y_k - q\sum_{i=1}^{N} a_{ii}; \quad a_i = b_1 \sum_{k=1}^{N} x_{ik} y_k; \quad a_{ii} = b_3 \sum_{k=1}^{N} (x_{ik}^{/2} - q) y_k; \quad a_{ij} = b_2 \sum_{k=1}^{N} x_{ik} x_{jk} y, \tag{4}$$

where: q - the value that provides the orthogonality of compositional plans:

$$q = \frac{1}{N}(2^n + 2R^2) = \frac{1}{15}(2^3 + 2 \cdot 1,215^2) = 0,73, \tag{5}$$

b_0, b_1, b_2, b_3 – elements of the plan matrix b_0 = 0.0667; b_1 = 0.0913; b_2 = 0.125; b_3 = 0.298.

The estimation of the errors' variance when calculating the estimates of the coefficients of the quadratic regression equation is calculated by the formulas:

$$S_{a0}^2 = \frac{b_0}{m} S_y^2 + q^2 \sum_{i=1}^{n} S_{aii}^2; \quad S_{ai}^2 = \frac{b_1}{m} S_y^2; \quad S_{aij}^2 = \frac{b_2}{m} S_y^2; \quad S_{aii}^2 = \frac{b_3}{m} S_y^2, \tag{6}$$

where: S^2_y - estimation of the reproduction dispersion:

$$S_y^2 = \frac{1}{N} \sum_{k=1}^{N} S_k^2. \tag{7}$$

Recommended form of the plan matrix and the results of experiments on Podolianka variety wheat seeds drying are presented in table 4.

Table 4

The plan matrix and the results of the experiments on Podolianka variety wheat seeds drying

№	Experimental conditions												τ, min	C, %
	x_1	x_2	x_3	x^2_1	x^2_2	x^2_3	$x_1 x_2$	$x_1 x_3$	$x_2 x_3$	x_1	x_2	x_3		
1.	-1	-1	-1	+1	+ 1	+1	+ 1	+1	+1	0.27	0.27	0.27	30	95
2.	+1	-1	-1	+1	+ 1	+1	-1	-1	+1	0.27	0.27	0.27	8	9
3.	-1	+1	-1	+1	+ 1	+1	-1	+1	-1	0.27	0.27	0.27	23	96
4.	+1	+1	-1	+1	+ 1	+1	+ 1	-1	-1	0.27	0.27	0.27	6	1
5.	-1	-1	+1	+1	+ 1	+1	+ 1	-1	-1	0.27	0.27	0.27	64	95
6.	+1	-1	+1	+1	+ 1	+1	-1	+1	-1	0.27	0.27	0.27	24	0
7.	-1	+1	+1	+1	+ 1	+1	-1	-1	+1	0.27	0.27	0.27	57	96
8.	+1	+1	+1	+1	+ 1	+1	+ 1	+1	+1	0.27	0.27	0.27	20	0
9.	-1.215	0	0	+1.472	0	0	0	0	0	0.75	-0.73	-0.73	42	93
10.	+1.215	0	0	+1.472	0	0	0	0	0	0.75	-0.73	-0.73	14	10
11.	0	-1.215	0	0	+1.472	0	0	0	0	-0.73	0.75	-0.73	28	96
12.	0	+1.215	0	0	+1.472	0	0	0	0	-0.73	0.75	-0.73	22.	94
13.	0	0	-1.215	0	0	+1.472	0	0	0	-0.73	-0.73	0.75	17	94
14.	0	0	+1.215	0	0	+1.472	0	0	0	-0.73	-0.73	0.75	31	90
15.	0	0	0	0	0	0	0	0	0	-0.73	-0.73	-0.73	25	93

After carrying out the experiments, the test of experiments' reproduction using the Cohren's criterion is carried out:

$$G_{\max} = \frac{S_{k\max}^2}{\sum_{k=1}^{N} S_k^2}, \tag{8}$$

where: S^2_k is the selective variance of the output quantity y in the k-line of the planning matrix, obtained from "m" of parallel experiments.

$$S_k^2 = \frac{1}{m-1} \sum_{l=1}^{m} (y_{kl} - y_l), \tag{9}$$

If $G_{\max} < G_{кр}$, with the number of degrees of freedom $v_1 = m - 1$, $v_2 = N$ and the level of significance $\alpha = 1 - \gamma$, then the hypothesis of dispersion homogeneity is accepted.

The hypothesis about the static significance of the estimates of the coefficients of the regression equation a_i is checked by means of t - the Stjudent's criterion:

$$t_{ip} = \frac{|a_i|}{S_{ai}}, \tag{10}$$

The verification of the mathematical model adequacy by the results of the experiment is carried out according to Fisher's criterion in the form of the ratio:

$$F_p = \frac{S^2_{inad}}{S^2_y}, \tag{11}$$

where: S^2_{inad} - estimation of inadequacy variance.

$$S^2_{inad} = \frac{1}{N-r}\sum_{j=1}^{N}(\overline{y_j} - \overset{\frown}{y_j}), \tag{12}$$

where: N - number of points of the orthogonal CCP;

r - number of significant parameters of the regression equation;

$\overset{\frown}{y_j}$ - the value of the response, calculated by the regression equation;

$\overline{y}$ - the average for the series "m" of experiments is the value of a real object reference.

If the condition is fulfilled:

$$F_p < F_{кр}, \tag{13}$$

then the mathematical model is considered adequate, that is, the scattering of the experimental values of the response relative to the values of the regression equation of the same order as the scattering, caused by the experimental errors.

The critical significance of the statistics is according to the corresponding tables for the given level of significance α and the degree of freedom $v_1 = N - r$ and $v_2 = N = (m - 1)$.

The results of a three-factor experiment on an orthogonal compositional plan of the second order are presented in the form of quadratic regression equations:

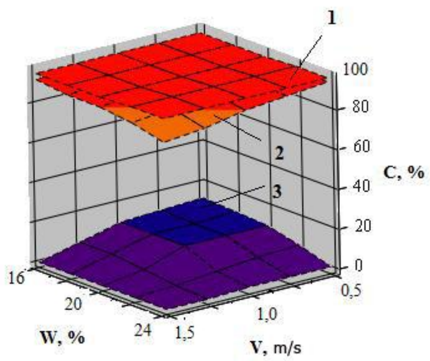
- for the germinating capacity of wheat seeds:

$$C = 160.4 - 3.618t - 25.06V - 2.53W - 0.16t^2 - 28.72V^2 - 0.57W^2 - 0.21tV - 0.026tW + 0.5VW; \tag{14}$$

- for drying time:

$$\tau = 204.72 - 0.54t - 13.65V + 7.78W + 0.01t^2 + 4.8\,V^2 + 0.13tV - 0.08tW. \tag{15}$$

Based on the regression equation of wheat seeds' germinating capacity and duration, the response surfaces are constructed (fig. 11).



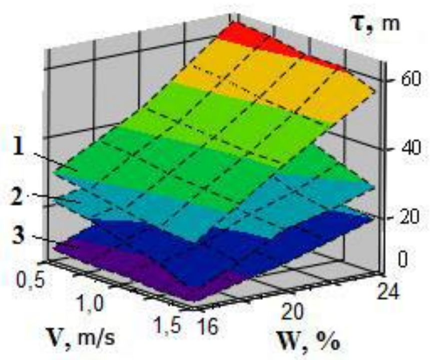


Fig. 11 – Surface response of the germinating capacity and duration of "Podolianka" variety wheat seeds at the action of the coolant temperature, °C

1 - 50; 2 - 65; 3 - 80

CONCLUSIONS

Analyzing the carried out research on the germination of "Podolianka" variety wheat seeds after drying, we can conclude:

- The temperature regime of drying is the most rational at a temperature of 50°C, the germination being 16%.
- At this temperature, the speed of the drying agent in the range v = 0.5...1.5 m/s does not significantly affect the germination.

- At this temperature, the initial moisture content of the grain in the range of 16-24% also does not significantly affect the germination.
- At the temperature of the drying agent of 65°C, the germination limits to 93-94% may be at velocity of the drying agent of 1.5 m/s and an initial moisture content of 20%, or at a velocity *v* = 0.5 m/s and an initial moisture content of 16% .
- At the increase in temperature of drying agent to 80°C, the germination is practically small (9%), which goes beyond agrotechnical requirements.

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