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Evaluation of the effect of microwave heating modes on the germination ability of lupine seeds

S V Vendin

Belgorod State University, 1, Vavilova ave, Maisky settlement, Belgorod region, Belgorod region, 308603, Russia

E-mail: Vendin_SV@bsaa.edu.ru

Abstract. Technologies based on the use of the energy of electric, magnetic and electromagnetic fields can be successfully applied in agricultural production. According to the available research results, it can be quite reliably asserted that during the pre-sowing treatment of agricultural seeds, it is possible to use microwave electromagnetic fields. A feature of such technologies is the experimental determination of the parameters of microwave exposure. The materials of the article contain the results of experimental studies to assess the temperature effect of microwave energy on the germination ability of lupine seeds. Regression equations are obtained in coded and natural variables to assess the effect of the final temperature and microwave heating rate on the germination ability of lupine seeds. Analysis of the results obtained indicates that the final result of microwave seed treatment depends on each factor separately and on their relationship. In addition, it is necessary to strictly observe the processing regimes, since the seeds are sensitive to energy effects and, in addition to the stimulation effect, you can get a negative result or get into the zone of insensitivity. According to the data obtained, the best result of microwave stimulation of lupine seeds is observed when the seeds are heated to 50 °C at a heating rate of 0.46 °C/s. Compared to the results of wheat seed treatment, higher final temperatures and microwave heating rates are required to stimulate lupine seeds. In addition, for a positive result of processing, it is necessary to take into account that the microwave heating rate of the seeds determines the final temperature of their heating. To stimulate lupine seeds, it is possible to recommend microwave heating to 50 - 51 °C at a microwave heating rate of 0.46 - 0.47 °C/s.

1. Introduction.

Technologies based on the use of the energy of electric, magnetic and electromagnetic fields can be successfully applied in agricultural production [1-10]. At the same time, it has been reliably established that during the pre-sowing stimulation of seeds, their disinfection, disinsection and drying, it is necessary to take into account not only the parameters of the electromagnetic field, but also the initial properties of the seeds. Only taking these features into account is it possible to obtain the expected effect of technological processing of seeds and chamois. Another important feature of technologies using the energy of electromagnetic fields is that biological objects are characterized by protective reactions. Therefore, the technological effect can be achieved only when certain levels of exposure parameters are reached. According to the available scientific data, it can be reliably asserted that the use of the energy of electromagnetic fields of ultrahigh frequency during the pre-sowing treatment of seeds makes it possible to increase the germination and germination ability of seeds. At the same time, the technological result of seed treatment depends on the level of influencing factors. However, for the practical use of



seed treatment technologies using the energy of electromagnetic fields, it is necessary to strictly observe the treatment modes in terms of exposure parameters. In this case, it becomes necessary to conduct experimental studies to establish a reliable relationship between the parameters of microwave exposure, the efficiency of treatment and the initial properties of seeds. A specific feature of microwave processing is the manifestation of dielectric heating of the product. Therefore, it is important to reliably establish the relationship between the speed, the final temperature of microwave heating and biological indicators of the effectiveness of microwave treatment of seeds, which will allow monitoring and control of microwave treatment modes. As the accumulated experience in conducting such studies shows, the significance of each of the influencing factors can be assessed only with the use of methods of statistical processing of the experimental results, and to predict the result, it is necessary to obtain regression equations (models) of the response function (germination, germination ability, etc.).

2. Results

Below are the results of an experimental study evaluating the thermal effect of microwave energy on lupine seeds. Experimental studies on the effect of microwave treatment on the ability of seeds to germinate. Lupine seeds (moisture 10.25%) were studied in the experiment. Directly for microwave treatment of seeds, we used an installation with a microwave generator with a power of 0.5 kW and a radiation frequency of 2450 ± 50 MHz. To increase the utilization rate of microwave energy and reduce energy losses into the surrounding space, the technological processing of seeds was carried out in a radio-hermetic working chamber.

The aim of the work was to reveal the regression dependence of the effect of the final temperature and microwave heating rate on the ability of seeds to germinate. Lupine seeds were used as the object of research. During the research, the specific power of microwave exposure (kW / kg) and the treatment time (s) were changed in the range from 0.83 to 1.10 kW / kg and from 40 to 60 s, and the initial and final temperatures of seeds ($^{\circ}\text{C}$) were measured. As a result, experimental data were obtained reflecting the effect of the final temperature and microwave heating rate on the ability of seeds to germinate.

The main results of the experiment and indicators of energy and germination ability of lupine seeds are shown in Table 1.

Table 1. Results of treatment of lupine seeds.

N	Initial temperature, $^{\circ}\text{C}$, t_0	Final seed temperature, $^{\circ}\text{C}$, t_k	Processing time, s	Heating rate, $^{\circ}\text{C/s}$, Θ	Germination ability, %	
					average	difference with control
1	20	44	41	0,59	87.0	+0.5
2	20	34	41	0,34	85.5	-1.0
3	20	54	61	0,56	86.5	0.0
4	20	49	60	0,48	88.0	+1.5
5	20	42	51	0,43	84.5	-2.0
6	20	45	51	0,49	87.5	+1.0
7	20	39	41	0,46	86.0	-0.5
8	20	52	60	0,53	87.5	+1.0
9	20	45	51	0,49	86.0	+0.5
10	The control				86.5	-

The experimental data were approximated by an incomplete second-order regression equation that takes into account the effect of the final temperature and microwave heating rate on the germination capacity of seeds in the range of final temperatures from 43 to 51.5°C at microwave heating rates from 0.46 to 0.51°C/s .

The reproducibility of the experiments was assessed using the Cochran test at the significance level $\alpha=0.05$ and the number of degrees of freedom $f_2 = 12$. The calculated value of the Cochran test G_{calc} did not exceed the permissible values $G_{0.05}(3.4)$ ($0.18 \leq 0.68$)

The regression equation for the effect of the final temperature and microwave heating rate on the germination capacity of lupine seeds in coded variables is:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_{12}X_1X_2, \quad (1)$$

where Y is the ability of seeds to germinate, %; X_1 is factor of the final temperature of microwave heating, p.u. ($-1 \leq X_1 \leq +1$), X_2 is factor of the microwave heating rate, p.u. ($-1 \leq X_2 \leq +1$); $B_0=86.50$; $B_1=1.00$; $B_2=0.50$; $B_{12}= - 0.75$.

The significance of the coefficients was checked by the Student's test (t_{cr}) at the significance level $\alpha=0.05$ and the number of degrees of freedom $f_2 = 12$. All the coefficients in equation (1) are significant, therefore the factors are sufficiently correlated with each other. The adequacy of the model was assessed by Fisher's criterion at a significance level of $\alpha=0.05$. The calculated value of the Fisher criterion F_{cal} did not exceed the permissible values $F_{0.05}(1, 12)$ ($0.20 \leq 4.75$).

The calculated regression equation in natural variables is obtained by replacing the coded variables in equation 1 with their natural counterparts in accordance with Table 1 using the formulas:

$$X_1 = (T - 47.25)/4.25, X_2 = (\vartheta - 0.51)/0.05, \quad (2)$$

where T is the factor of the final temperature of microwave heating, °C ($43 \leq T \leq 51.5$); ϑ is the factor of the microwave heating rate, °C/c ($0.46 \leq \vartheta \leq 0.51$).

One of the forms of the calculated regression equation in natural variables can be represented as follows:

$$Y = B_0 + B_1 \left(\frac{T-47.25}{4.25} \right) + B_2 \left(\frac{\vartheta-0.51}{0.05} \right) + B_{12} \left(\frac{T-47.25}{4.25} \right) \left(\frac{\vartheta-0.51}{0.05} \right), \quad (3)$$

3. Process analysis

Figure 1 below shows the calculated surface of the germination ability for lupine seeds, depending on the natural values of the microwave heating rate (°C/s) and the final temperature (°C). The germination ability of the control seeds was 86.5%.

The presented surface of the influence of the speed and final temperature of microwave heating on the germination ability shows that the effect of technological processing is determined by the relationship of both influencing factors. Areas (modes) of stimulation, oppression and zones of insensitivity can be noted.

At the same time, it can be unambiguously asserted that the best result of microwave treatment is observed when seeds are heated to 50 °C at a heating rate of 0.46 °C/s. Compared to the results of processing wheat seeds [9], the stimulation of lupine seeds requires higher values of the final temperature and microwave heating rate. In addition, for a positive result of processing, it is necessary to take into account that the microwave heating rate of the seeds determines the final temperature of their heating. Therefore, to stimulate lupine seeds, it is possible to recommend microwave heating to 50 - 51 °C at a microwave heating rate of 0.46 - 0.47 °C/s.

4. Conclusion

The results of experimental studies on the effect of temperature regimes of microwave treatment of lupine seeds on the ability to germinate are presented.

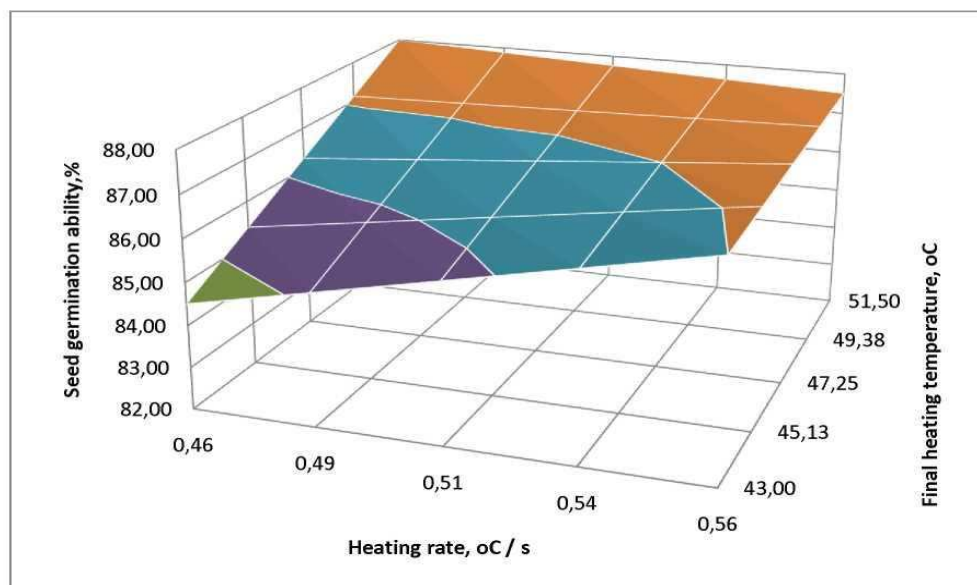


Figure 1. Changes in the germination ability of lupine seeds after microwave treatment.

As a result of the research, regression equations in coded and natural variables were obtained to assess the effect of the final temperature and microwave heating rate on the germination ability of lupine seeds.

It has been established that the effect of technological processing is determined by the relationship of both influencing factors. Areas (modes) of stimulation, oppression and zones of insensitivity can be noted. At the same time, it can be unambiguously asserted that the best result of microwave treatment is observed when seeds are heated to 50 °C at a heating rate of 0.46 °C/s. Compared to the results of processing wheat seeds [9], the stimulation of lupine seeds requires higher values of the final temperature and microwave heating rate. In addition, for a positive result of processing, it is necessary to take into account that the microwave heating rate of the seeds determines the final temperature of their heating. Therefore, to stimulate lupine seeds, it is possible to recommend microwave heating to 50 - 51 °C at a microwave heating rate of 0.46 - 0.47 °C/s.

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