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OPTIMIZATION OF PARAMETERS OF A VIBROCONVEYOR SYSTEM FOR INFRARED DRYING OF SOY

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ABSTRACT

This paper proposes a method to determine the optimal parameters for the drying of soybean using a kinematic vibration dryer. Among the main parameters of the investigated vibroconveyor are heat and mass transfer, physical and mechanical. The paper presents a mathematical

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model of the dependence of parameters of the soybean drying process of soybean built based on experimental data obtained by organizing an effective experiment plan with a sufficiently large number of factor levels. To determine the rational parameters for drying soybean, it is important to build the most accurate and adequate mathematical model, which will determine the most accurate values of the required parameters. For this purpose, it is recommended to conduct an experiment with as many levels of factors as possible. The article proposes an experiment established on a dedicated balanced orthogonal plan, which is optimal according to the D-efficiency criterion. Based on the experimental data, an adequate mathematical model of the dependence of the drying characteristics of soybean (moisture of the processed material (%), temperature inside the product layer (°C) on the parameters – vibration amplitude (mm), distance from the conveyor surface (mm), radiation power (Wt), weight ($g \cdot min^{-1}$). Following the analysis of the constructed mathematical model, optimal parameters of the developed vibroconveyor infrared dryer were substantiated. The main characteristics of the vibroconveyor mechanism of interoperational transportation of bulk products in the working area were also determined, and a technical and economic analysis of the developed oscillatory system was conducted.

Introduction

The agricultural industry is one of the most important in the economy of any country. The most important stage in food production, along with the cultivation of agricultural crops, is the organization of the storage process (Faichuk et.al., 2022; Lutsiak et.al., 2021).

Drying grain as a technological method is a well-known method of protecting raw materials from spoilage **(**Palamarchuk et al., 2015; Palamarchuk et al., 2017**)**. The increase in grain production by the agricultural sector of Ukraine is inextricably linked with the need to constantly improve the technology of basic operations of grain processing after harvest, and, above all, drying. This operation determines the quality of crop conservation. Since the main purpose of drying is to remove excess moisture from the grain to increase its stability during storage, the main requirement for the drying process is to maintain the technological quality of the grain. One of the most effective drying methods is infrared drying, which uses infrared radiation. Under the condition of using infrared radiation, the duration of heat treatment is significantly reduced due to the lack of thermal resistance of the boundary layer of the product to the radiation flux, the energy of which is directly absorbed by the surface of the raw material particles (Cook and Nachtrheim, 1980; Atanazevich, 2000).

The main parameters of the drying mode are the temperature and speed of the drying agent, the temperature of grain heating in the drying chamber, the thickness of the grain layer in the direction of movement of the drying agent, and the exposure of the heating process. One of the most effective ways to intensify drying processes is to use vibration. The result of the influence of this technological factor is intensive circulation and relative movement of product particles in the working chamber along different trajectories, providing optimal conditions for heat and mass transfer. Moreover, it allows a broad scope of regulating vibration parameters, which allows for processing significant volumes of production, in different distances (Malkina et al., 2019; Samoychuk et al., 2020).

The choice of optimal processing modes for the developed vibroconveyor is based on a comprehensive analysis of the results of theoretical and experimental studies of the main parameters of the installation.

Many works **(**Kuhfeld, 2010; Cook and Nachtrheim, 1980; Bartel and Sherbert, 2000) are devoted to the problem of constructing balanced optimal designs.

Al Labadi (2015), Atkinson end Donev (1989), Atwood (1973), Yu (2011), Meyer and Nachtsheim (1995), Sagnol and Harman (2015) proposed a number of algorithms and approaches to construct plans based on the D-efficiency criterion. Kuhfeld (2010) proposed an effective approach and a computational algorithm to construct a D-optimal orthogonal balanced experimental design, m^n, where m is the number of levels of factors, and n is the number of factors.

Jung and Yum (1996), Nguyen and Miller (1992) proposed a mathematical model that describes the operation of the vibrowave infrared drying model. Based on the experimental data, rational values of the parameters (factors) of the equipment operation are determined. In this paper, we consider a mathematical model of the process of vibratory drying of soybean, built on the basis of experiments with five factors at five levels each. To build the model, an orthogonal balanced design scheme is used, built on the basis of special block operations on matrices. The optimal values of the parameters of drying are established based on a mathematical model constructed from the results of the experiment.

A full factorial experiment gives the most complete information about the object of research for a given number of factors and their levels. In this design, the columns of the matrix are not correlated, and the design is orthogonal and balanced. However, a significant drawback of such a plan is the need for a large number of experiments. So, for example, with five factors, each of which varies at five levels, it is necessary to carry out 5^4=625 experiments. This significantly limits the use of such plans.

One of the ways to obtain sufficiently complete information about an object while reducing the number of required experiments is to build a fractional plan. In this case, it is possible to use not the entire matrix of the design of the full factorial experiment, but only some of its rows. In this case, the matrix of the plan must be constructed in such a way that even part of the information fully reflects the object under study. In other words, the plan must be effective.

One of the indicators of the quality of the plan completeness is the fact that each factor at each level is repeated in the plan matrix the same number of times, that is, the matrix of such a plan forms an orthogonal array and the plan is balanced (Kuhfeld, 2010).

The plan built on the basis of an orthogonal array is balanced, since it contains the same number of each level of each factor, each pair of factors occurs the same number of times. If the plan is balanced and its matrix is orthogonal, then the criterion of D-efficiency of such a plan is of greatest importance. According to this criterion, the expected forecast error based on the response function is minimal.

Purpose and scope of work

The purpose of the article is to prove the operating parameters of the developed vibroconveyor infrared dryer for soybean based on the analysis of a mathematical model. The mathematical model is built based dedicated orthogonal (balanced) experimental design, optimized according to the adopted criteria.

To study the technological, energy, and design parameters under infrared radiation for the efficiency of moisture removal from the product, an experimental model of a vibration-wave infrared dryer was developed (schematically shown in Fig. 1). The model includes a conveyor for transporting the processed soybean seeds.

Following a dedicated experiment, a mathematical model was built, which allowed substantiating the operating parameters of the developed vibroconveyor infrared dryer, and to carry out its technical and economic analysis.

In this work, the problem of constructing a mathematical model of the work of an experimental model of a vibrowave infrared dryer is solved by organizing an effective scheme (plan) for conducting experiments with a sufficiently large number of factor levels and, at the same time, a small number of experiment repetitions.

Since the purpose of this study is to build an effective plan for conducting an experiment with a large number of factor levels and with the subsequent determination of the optimal values of factors based on the constructed model, the most appropriate criterion is D-optimality.

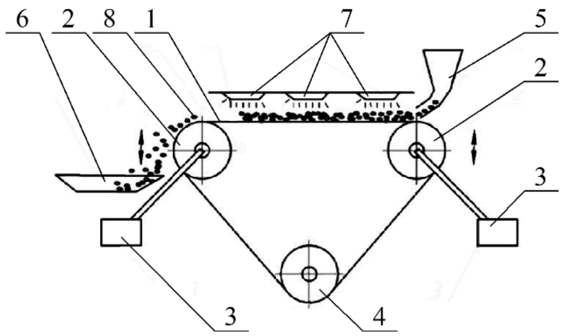

Figure 1. Experimental installation for studying the operation of the vibroconveyor infrared dryer: 1 – conveyor; 2 – rollers; 3 – lever; 4 – tension roller; 5 – feeder; 6 – collector; 7 – infrared emitters; 8 – processed material

The vibroconveyor system was analyzed according to the kinematic, power, and energy evaluation criteria. The amplitude of vibrations was investigated as kinematic characteristics and determined using equipment made by the company Robotron. Its previbration sensors were rigidly mounted on the vibrating surface and then signals from the sensors were captured using oscilloscopes and converted into physical quantities (Palamarchuk et al., 2016; Ginzburg, 1973; Palamarchuk et al., 2017).

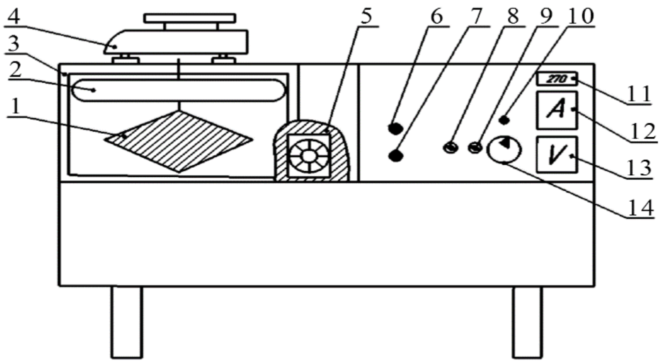

Figure 2. An installation scheme for drying using an infrared irradiator: 1 – basket; 2 – infrared illuminator; 3 – drying chamber; 4 – electronic scales; 5 – exhaust fan; 6, 7 – switch and switch of installation; 8 – fan switch; 9 – infrared illuminator switch; 10 – temperature parameter switch; 11 – power regulator; 12 – voltmeter; 13 – ammeter, 14 – product temperature indicator

To determine the main parameters of infrared radiation, e.g., the temperature in the processing area, the power of the emitters, the mass characteristics of the sample during thermal exposure, the equipment shown in Figure 2 was used (Jung and Yum, 1996; Nguyen and Miller, 1992).

The temperature was changed by adjusting the amount of electric power and the distance of the product to the source of infrared radiation.

When the measurements were made, a basket with a sample of the test product was placed inside the drying chamber, which is connected to the electronic scales using a copper wire. Using a special regulator set the required power of the infrared illuminator (Bandura et al., 2015).

To measure the temperature, a chromel-alumel thermocouple connected to a potentiometer was used, with a display of temperature data on the indicator. AQUA-15 grain moisture meter was used to determine the moisture content of the products (Palamarchuk et al., 2015; Ivanyshyn et al., 2020; Yermakov et al., 2019; Ginzburg, 1973).

Research results

After collecting the material and compiling the results of the evaluation of selected suppliers, the results were summarized in the form of tables broken down into individual product groups. The tables contain detailed information on the evaluation of each supplier with a detailed listing by individual indexes. It also contains collective information for the entire assortment group. Data analysis was performed to determine the current quality level of delivery for the selected criteria. Based on the data obtained and the adopted scores, following an evaluation, the suppliers were awarded appropriate results and their status was color-marked.

The optimal drying parameters of soybean were determined based on a study of the mathematical model. To build a mathematical model, experimental studies were organized and conducted according to a specially constructed plan (Schneid, 2010; Schubert, 2005; Bulgakov et al., 2020; Palamarchuk et al., 2019; Yermakov et al., 2021a; Yermakov et al., 2021b; Tryhuba et. al., 2022; Samoichuk et al., 2020).

On the basis of preliminary researches the following factors were defined: amplitude of fluctuations A (mm), distance from a surface d (mm), power of radiation N, (W), material supply ($g \cdot min^{-1}$) (Bulgakov et al., 2020; Palamarchuk et al., 2017).

The parameters y_1 – moisture of the processed material (%) and y_2 – temperatures in the middle of the grain material layer, (°C).

Each factor varied at five levels. The values of the levels of variation of the factors are given in Table 1.

Table 1.
Levels of measurement of factors influencing the process of drying soybean seeds

Factors	Natural designations	Coded designa-tions	Factor levels				
			4	3	2	1	0
Amplitude of oscillations, mm	(A)	x_1	5	4.125	3.25	2.375	1.5
Distance from the surface of the conveyor, (mm)	(d)	x_2	25	22.5	20	17.5	15
Radiation power, (W)	(N)	x_3	400	375	350	325	300
Material supply, ($g \cdot min^{-1}$)	(m)	x_4	2300	2475	2650	2825	3000

In work (Malkina et al., 2019), a special technique is proposed for constructing a balanced orthogonal design of type m^n, which is optimal by the criterion of D-efficiency.

According to this technique, a matrix of the orthogonal design of the experiment of the form 45 is proposed (m = 5 is the number of factor levels, n = 4 is the number of factors). Number of repetitions of the surface experiment 3. Table 2 shows the matrix of the experiment and the average knowledge of the responses y_1 – the content of the cut material (%), y_2 – temperature in the middle of the ball of the grain material, (°C).

Table 2.
Balanced orthogonal experiment design matrix

No.	z_1	z_2	z_3	z_4	y_1	y_2
1	0	0	0	0	13.8	41
2	0	1	2	3	11.7	52
3	0	2	4	1	12.8	45
4	0	3	1	4	11.2	54
5	1	1	1	1	12.9	45
6	1	2	3	4	11.2	56
7	1	3	0	2	12.4	47
8	1	4	2	0	13.4	40
9	2	2	2	2	12.3	49
10	2	3	4	0	13.2	42
11	2	4	1	3	11.8	51

12	2	0	3	1	12.8	47
13	3	3	3	3	11.8	53
14	3	4	0	1	12.9	44
15	3	0	2	4	11.1	57
16	3	1	4	2	12.2	50
17	4	4	4	4	11.5	57
18	4	0	1	2	12.2	50
19	4	1	3	0	13.1	44
20	4	2	0	3	11.8	52

y_1 – moisture of the processed material (%),

y_2 – temperatures in the middle of the layer of grain material, (℃).

After constructing the plan for constructing the orthogonal matrix of the plan, standardized orthogonal coding was performed (Cook and Nachtrheim, 1980), that is, the calculation factors were replaced with a set of coded variables according to the relations:

Level 0	1.58	-0.91	-0.65	-0.50
Level 1	0	1.83	-0.65	-0.50
Level 2	0	0	1.94	-0.50
Level 3	0	0	0	2.00
Level 4	-0.28	-0.91	-0.65	-0.50

As a result, an orthogonal balanced plan was constructed, which has the best D-efficient parameter among plans of the same dimension (Malkina et al., 2019).

On the basis of experimental data (Table 2), mathematical models were built for each of the studied parameters.

The mathematical model for the y_1-value of the material (%), has the following form (taking into account only the significant parameters of the model):

$$y_1 = -6.3635 + 0.5442x_1 + 0.1565x_2 + 0.0160x_3 \\ + 0.0071x_4 - 6.5\cdot10^{-6}x_2 x_4 - 0.00022x_1x_4 - 5.6\cdot10^{-5}x_2x_4$$

where:

x_1 – amplitude of oscillations, (mm)

x_2 – distance from the surface of the conveyor, (mm)

x_3 – radiation power, (W)

x_4 – material supply, ($g\cdot min^{-1}$)

For the indicator y_2 – the value of the temperature in the middle ball of the grain material (℃), the mathematical model takes on the following form (taking into account only the significant parameters of the model)

$$y_2 = 98.0365 + 0.5186x_1 - 0.1863x_2 + 0.0177x_3 - 0.0202x_4$$

where:

x_1 – amplitude of oscillations, (mm)

x_2 – distance from the surface of the conveyor, (mm)

x_3 – radiation power, (W)

x_4 – material supply, (g·min^{-1})

Based on the Fisher criterion, the adequacy of the constructed models was proved. The calculated value of the Fisher test for the first model is F_p = 1790.24, and for the second model it is F = 1415.23. The mathematical models are adequate at a significance level of 0.05.

The analysis of the constructed model allows to determine rational values of drying parameters. As observed, the rational values of the humidity of the processed material are 12.35 - 12.45%. On the basis of model (1) we find the corresponding values of drying parameters: amplitude of fluctuations A = 3.5 ± 0.45 mm, distance from the surface of the conveyor d = 20 ± 1.3 mm, radiation power N = 350 ± 13 W, weight, m = 2670 ± 90 g·min^{-1}.

Rational values of temperature in the middle of the layer of grain mass ranged from 47 to 50°C. According to the constructed model (2), this temperature value is reached at the following parameter values: amplitude of fluctuations A = 3.9 ± 0.45 mm, distance from a conveyor surface, d = 19 ± 1.3 mm, radiation power N = 355 ± 13 W, material supply, m = 2675 ± 90 g·min^{-1}.

Conclusions

1. To determine the rational parameters of the vibroconveyor infrared drying of soybean, experimental studies were conducted according to a specially organized experimental plan. Due to the fact that the proposed plan has the property of balance and D-efficiency, the mathematical model allows for an effective analysis of the influencing factors.
2. The experimental data according to the research plan allowed to substantiate the mode parameters of the developed vibroconveyor infrared dryer, the main characteristics of the vibration wave mechanism of interoperative transportation of bulk products in the working area, and to conduct technical and economic analysis of the developed vibration system.
3. Using the discussed soybean drying method is rational at the following parameters: amplitude of 3.5-3.9 mm, distance from a surface of 19-20 mm, radiation power of 350-355 W, material supply of 2670-2675 g·min^{-1}. At the same time the optimum value of humidity of soybean is 12.35-12.45 % and temperature in the center of gravity of the grain is 45-47°C.

References

Al Labadi, L. (2015). Some refinements on Fedorov's algorithms for constructing D-optimal designs. *Brazilian Journal of Probability and Statistics*, *29*(1), 53-70.

Atanazevich, V. I. (2000). Drying food. *Reference Manual. Moscow: DeLi*.

Atkinson, A. C., & Donev, A. N. (1989). The construction of exact D-optimum experimental designs with application to blocking response surface designs. *Biometrika*, *76*(3), 515-526.

Atwood, C. L. (1973). Sequences converging to D-optimal designs of experiments. *Annals of Mathematical Statistics. 1*, 342-352.

Bandura, V., Turcan, O., & Palamarchuk, V. (2015). Experimental study of technological parameters of the process of infrared drying of a moving ball of oilseed crops. *MOTROL Commission of Motorization and Energetics in Agriculture*, *17*(4), 211-214.

Bartel, R. G. & Sherbert, D. R. (2000). *Introduction to Real Analysis*. New York: Wiley.

Bulgakov, V., Nikolaenko, S., Kiurchev, S., Pascuzzi, S., Arak, M., Santoro, F., Olt, J. (2020). The theory of vibrational wave movement in drying grain mixture. *Agronomy Research*, *18*(2), 360-375.

Cook, R. D., & Nachtrheim, C. J. (1980). A comparison of algorithms for constructing exact D-optimal designs. *Technometrics*, *22*(3), 315-324.

Faichuk, O., Voliak, L., Glowacki, S., Pantsyr, Y., Slobodian, S., Szeląg-Sikora, A., & Gródek-Szostak, Z. (2022). European Green Deal: Threats Assessment for Agri-Food Exporting Countries to the EU. *Sustainability, 14,* 3712.

Ginzburg, A.S. (1973). *Drying food*, M.: Food industry, 528.

Ivanyshyn, V., Yermakov, S., Ishchenko, T., Mudryk, K. (2020). Calculation algorithm for the dynamic coefficient of vibro-viscosity and other properties of energy willow cuttings movement in terms of their unloading from the tanker. In *E3S Web of Conferences*, *154*, 04005.

Jung, J. S., & Yum, B. J. (1996). Construction of exact D-optimal designs by Tabu search. *Computational Statistics & Data Analysis*, *21*(2), 181-191.

Kiurchev, S., Verkholantseva, V., Kiurcheva, L., & Dumanskyi, O. (2020). Physical-mathematical modeling of the vibrating conveyor drying process of soybeans. Latvia University of Sciences and Techologies Faculty of Engineering. Jelgava, 991-996.

Kuhfeld, W. F. (2010). Experimental design, efficiency, coding, and choice designs. *Marketing research methods in sas: Experimental design, choice, conjoint, and graphical techniques*, 47-97.

Lutsiak, V., Hutsol, T., Kovalenko, N., Kwaśniewski, D., Kowalczyk, Z., Belei, S., & Marusei, T. (2021). Enterprise Activity Modeling in Walnut Sector in Ukraine. *Sustainability*, *13*(23), 13027.

Malkina, V., Kiurchev, S., Osadchyi, V., & Strokan, O. (2019). The formation of orthogonal balanced experiment designs based on special block matrix operations on the example of the mathematical modeling of the pneumatic gravity seed separator. In *Modern Development Paths of Agricultural Production* (pp. 111-119). Springer, Cham.

Meyer, R. K., & Nachtsheim, C. J. (1995). The coordinate-exchange algorithm for constructing exact optimal experimental designs. *Technometrics*, *37*(1), 60-69.

Nguyen, N. K., & Miller, A. J. (1992). A review of some exchange algorithms for constructing discrete D-optimal designs. *Computational Statistics & Data Analysis*, *14*(4), 489-498.

Palamarchuk, I. P., Tsurkan, O. V., & Palamarchuk, V. I. (2015). The analysis of theoretical and experimental research results of infrared vibrowave conveyer dryer main parameters. *TEKA. Commissionof Motorization and Power Industry in Agriculture*, *15*(4), 314-323.

Palamarchuk, I., Kiurchev, S., Kiurcheva, L., & Verkholantseva, V. (2019). Analysis of Main Process Characteristics of Infrared Drying in the Moving Layer of Grain Produce. In *Modern Development Paths of Agricultural Production* (pp. 317-322). Springer, Cham.

Palamarchuk, I., Tsurkan, O., Palamarchuk, V., & Kharchenko, S. (2016). Research of competitiveness of vibrowave infrared conveyor dryer for postharvest processing of grain. *Eastern-European Journal of Enterprise Technologies*, *27*(8), 79-85.

Palamarchuk, I.P., Drukovany, M.F., Pala-Marchuk, V.I., & Burova Z.A. (2017). Vibromechanical intensification of drying processes of oil-containing raw materials: monograph row. "COMPRINT", 325.

Sagnol, G., & Harman, R. (2015). Computing exact $ D $-optimal designs by mixed integer second-order cone programming. *The Annals of Statistics*, *43*(5), 2198-2224.

Samoychuk, K.O., Kiurchev, S.V., Yalpachik, V.F., Palyanichka, N.O., Verkholantseva, V.O., Lomeyko, O.P., (2020). *Innovative technologies and equipment industries*. Processing of crop products: A guide. Melitopol, 307.

Schneid, S. (2010). PAT in freeze drying: monitoring of product pesistance using non-invasive NIR-spectroscopic TDLAS measurements/S. Schneid, H. Gieseler. Proc. 7th World Meeting on Pharmaceutics, Biopharmaceutics and Pharmaceutical Technology, Valetta, Malta, March 8-11.

Schubert, H., Regier, M., & Knoerzer, K. (Eds.). (2005). *The microwave processing of foods*. Taylor & Francis US.

Tryhuba, A., Kubon, M., Tryhuba, I., Komarnitskyi, S., Tabor, S., Kwaśniewski, D., Faichuk, O., Hohol, T. (2022). Taxonomy and Stakeholder Risk Management in Integrated Projects of the European Green Deal. *Energies, 15*, 2015.

Yermakov S., Hutsol T., Rozkosz A., Glowacki S., Slobodian S. (2021a). Evaluation of Effective Parameters of Biomass Heat Treatment in Processing for Solid Fuel. *Engineering for Rural Development. 241,* 1114-1119.

Yermakov, S., Hutsol, T., Glowacki S., Hulevskyi V., & Pylypenko V. (2021b). Primary Assessment of the Degree of Torrefaction of Biomass Agricultural Crops. *Environment. Technologies. Resources, 241,* 264-267.

Yermakov, S., Taras, H., Mudryk, K., Dziedzic, K., & Mykhailova, L. (2019). The analysis of stochastic processes in unloadingthe energywillow cuttings from the hopper. *Environment. Technologies. Resources. Proceedings of the International Scientific and Practical Conference*, *3*, 249-252.

Yu, Y. (2011). D-optimal designs via a cocktail algorithm. *Statistics and Computing, 21,* 475-481.

OPTYMALIZACJA PARAMETRÓW WIBRACYJNEJ SUSZARKI DO SOI

Streszczenie. W pracy zaproponowano metodę wyznaczania optymalnych parametrów suszenia soi za pomocą suszarki z funkcją kinematycznego wzbudzania drgań. Główne parametry badanego urządzenia to wymiana ciepła i masy oraz właściwości fizyczne i mechaniczne. W celu przeprowadzenia badań zbudowano model matematyczny zależności między wskaźnikami procesu suszenia soi na podstawie danych doświadczalnych uzyskanych poprzez zorganizowanie efektywnego schematu doświadczenia z odpowiednio dużą liczbą poziomów czynników. By określić racjonalne parametry suszenia soi należy zbudować jak najdokładniejszy i adekwatny model matematyczny, który wyznaczy najdokładniejsze wartości wymaganych parametrów. W artykule zaproponowano przeprowadzenie eksperymentu na specjalnie skonstruowanym zrównoważonym planie ortogonalnym, optymalnym według kryterium D-efektywności. Na podstawie danych eksperymentalnych opracowano odpowiedni model matematyczny zależności charakterystyki suszenia soi (wilgotność przetwarzanego materiału (%), temperatura wewnątrz warstwy produktu (°C) od parametrów – amplitudy drgań (mm), odległości od powierzchni przenośnika taśmowego (mm), mocy promieniowania (W_t), masy ($g \cdot min^{-1}$). Analiza zaproponowanego modelu matematycznego pozwoliła uzasadnić optymalne parametry opracowanej wibrosuszarki na podczerwień, główne cechy mechanizmu wibracyjno-falowego do transportu produktów sypkich w obszarze roboczym oraz przeprowadzić analizę techniczno-ekonomiczną opracowanego systemu oscylacyjnego.

Słowa kluczowe: schemat doświadczeń, kryterium efektywności D, model matematyczny, suszenie, optymalizacja, system