

## KINETIC FEATURES OF VIBRATING AND FILTRATION DEWATERING OF FRESH-PEELED PUMPKIN SEEDS

### ОСОБЛИВОСТІ КІНЕТИКИ ВІБРАЦІЙНО-ФІЛЬТРАЦІЙНОГО ЗНЕВОДНЕННЯ СВІЖЕОЧИЩЕНОГО НАСІННЯ ГАРБУЗА

Ph.D. Tsurkan O.V.<sup>1)</sup>, Eng. Gerasimov O.O.<sup>1)</sup>, Ph.D. Polyevoda Y.A.<sup>1)</sup>, Ph.D. Tverdokhlib I.V.<sup>1)</sup>,  
Ph.D. Rimar T.I.<sup>2)</sup>, Ph.D. Stanislavchuk O.V.<sup>3)</sup>

<sup>1)</sup>Vinnitsa National Agrarian University / Ukraine; <sup>2)</sup>National University "Lviv Polytechnic" / Ukraine,

<sup>3)</sup>Lviv State University of Life Safety / Ukraine

Tel: +380672152088; E-mail: igor\_tverdokhlib@yahoo.com

**Keywords:** vibration and filtration dewatering, pumpkin seeds, drying coefficient, vibration.

#### ABSTRACT

Drying coefficients depending on the main process parameters of fresh-peeled pumpkin seeds (FPPS) vibration and combined dehydration and relative drying coefficient on the basis of the constructed graphic dependence are defined. Dependences for calculation of moisture and time of FPPS dewatering in the studied change range of drying process parameters are displayed.

#### РЕЗЮМЕ

Визначено коефіцієнти сушіння залежно від основних параметрів процесу вібраційно-фільтраційного зневоднення свіжеочищеного насіння гарбуза (СОНГ) та відносний коефіцієнт сушіння на основі побудованої графічної залежності. Виведено залежності для розрахунку вологості та часу зневоднення СОНГ в досліджуваному діапазоні зміни параметрів процесу сушіння.

#### INTRODUCTION

At present stage of industry development technical and economic policy of conserving resources becomes increasingly important. It requires the implementation of new scientific ideas and technologies in production intensification. Following a strict regime of economy of raw materials, fuel and energy with simultaneous intensification technologies can be up to 75...85% increase in inputs. Drying, as a process, is the main production stage and most significantly affects its economic indexes (Rymar T., 2009), accounting for about 20% of total production costs (Poperechnyj A., 2007).

It is known that high-intensity filtering dehydration is dispersed by drying and sheet material and has advantages over traditional methods of dehydration, such as: the availability period of the free moisture mechanical displacement; the use of thermal agent with low temperature capabilities; reducing costs of thermal energy in the process, increasing the speed of drying; improving the quality of drying materials, avoiding stage of cleaning agent heat (Mykychak B. et al, 2012). Significant prospects for improving the efficiency of dehydration of fresh-peeled pumpkin seeds (FPPS), as a subject to final sowing and food (pharmaceutical) demands is a combination of filtration and dewatering vibrating action, requiring an in-depth theoretical and experimental study.

Many authors (Hanyk Ya., 1992; Atamanjuk V., 2007; Stanislavchuk O., 2007) have devoted their papers to the investigation of heat and mass transfer process during drying of materials of different nature, while (Tsurkan O. et al, 2014) researched the process vibration filtration dehydration of FPPS, a paper based on experimental data and where is obtained basic analytical dependence describing the process hydrodynamics. In the work (Tsurkan O. et al, 2015), it is shown the time dependence of the critical speed and vibration-filtration dehydration, and proved dominant influence pressure drop and vertical oscillations of dehydration intensity of high damp fresh-peeled pumpkin seeds in the first drying period on the basic parameters of the process. Theoretical and experimental study of heat transfer processes during the second period of filtration, dispersed materials drying is considered in detail (Atamanjuk V. and Gumnytskyj Ya., 2009). Energy and technical, technological aspects of drying process intensification of high damp seeds, including pumpkin seeds, are covered in (Palamarchuk I. et al, 2016).

In the article, we generalize the vibration kinetics and combined dehydration of FPPS in the second period and set dependencies for calculating humidity and FPPS dehydration time in the test range changing process parameters, in particular, the ratio of vertical and horizontal components of the vibration amplitude at a vibration frequency  $f = 15$  Hz revs of stirrer-cleaner  $n$  from 0 to 1.2 r/min, as auxiliary operating parameters, in the vibrating dryer (Palamarchuk I. et al, 2016).

## MATERIAL AND METHODS

Based on own studies (Tsurkan O. et al, 2009) and the existing ones (Holubkovych A., 1986) we determined the type of relation of moisture and material and the corresponding interval limits of FPPS humidity, making it possible to justify the dehydration rational ways (table 1) and the corresponding constructive scheme of drying equipment (Pravdjuk N. et al, 2011). In general, the process of combined dehydration of FPPS, of the 1st class of cleaning seeds and surface layer (according to the classification given in (Holubkovych A., 1986), also depending on the type of material, and moisture relation based on moisture intervals (table 1) can be divided into two conditional periods. In the first period of FPPS dehydration, humidity changes in the range 44 – 52% as typical mechanical removal of moisture through the channels between seeds (BSC) – macro pore layer of FPPS and pre-slight warming of seeds. For the second period of combined dehydration of FPPS humidity changes within 44 – 38% as typical decreasing drying speed and kinetic curves depicted curved sections, the angle of which indicates a slowdown in the process of dehydration (Tsurkan O. et al, 2015). This can be explained by the fact that the amount of moisture, delayed both by adsorption forces (bridging, drip, wet point) and surface tension forces on the seeds surface, is gradually reducing, and the process of evaporation due to heat small seeds is quite slow.

After removing moisture through BSC, the layer of FPPS still contains a significant amount of moisture that is delayed both by adsorption forces and due to the presence of blind channels from which moisture is replaced. In through BSC of complex form streams of drying agent turbilize, tear film of moisture in the form of small droplets of fog and render them out of material structure.

To reach the humidity range of about 38% cohesive-adhesive properties of seed layer are weakened, and seed acquires discrete properties (table 1).

Table 1

Rational methods of FPPS dehydration depending on type of relationship between moisture and the material

Type of moisture relation during dehydration	The hydrodynamic characteristics of FPPS	Rational way of dehydration		The driving factors and the intensification of dehydration process
		Filtration dehydration	Convection drying	
Capillary $W_{ca} = (52- 47)\%$	Local drag reduction adjacent to vibrating surfaces of LFPPS	Filtering displacement of moisture from cross-mating BSC "top-down"	Preheat of LFPPS, slight evaporation of moisture	Submission of a drying agent of FPPS "top-down" • Slight heating of the drying agent ( $t = 30^{\circ}\text{C}$ ) • Dilution under FPPS ( $P_d = 450$ Pa) • Vibration action • Preferably vertical vibrations • The mechanical mixing of LFPPS • Cleaning of perforated surfaces of supply-drying agent selection
		Displacement of moisture from the deadlock, non-connected BSC "top-down"		
	Fluidization, destruction of cohesive-adhesive bonds	Two phase movement drip-air mixture "top-down"		
Rope $W_r = (47- 44)\%$	Reduction of hydrodynamic resistance, ability to aerovibroboiling	Two-phase movement drip-air mixture "bottom-up"	Intense convective drying in AVBL	Vibration performance, stable AVBL • Filing drying agent «bottom-up» • Heating drying agent ( $t_{da2} = 50^{\circ}\text{C}$ ) • Pre-heating of seeds ( $t_{s1} = 26^{\circ}\text{C}$ )
Capillary-butt (glands) $W_{cb} = (44-38)\%$				
Capillary-butt (spot) $W_{cb} = (38-24)\%$				
Surface film-drop $W_{sf} = (24-15)\%$				
Inside physico-chemical relation $W_{ph\ ch} = (15-10)\%$				

Note: LFPPS – layer of fresh-peeled pumpkin seeds; AVBL – aerovibroboiling layer. Highlight: vibration filtration, dewatering study method.

Under the influence of vibration and drying agent flow in the direction of "perforated bottom – a layer of seeds" created aerovibroboiling layer (AVBL), which can increase the temperature of the drying agent and significantly intensify the process of dehydration, which can be divided into two periods: the constant and the decreasing speed drying.

In this article, we studied the kinetics of the second period of vibration filtration dehydration of FPPS within the humidity range 44 – 38%.

Experimental studies were conducted using research and industrial design vibration dryers, developed and manufactured at the processes and equipment department for food processing industries named by Professor P.S. Bernik Vinnytsia, National Agrarian University, realizing vibration filtration dehydration and convective drying AVBL (*Pravdjuk N. et al, 2011*).

To summarize the kinetics vibration filtration dehydration of FPPS in the second period we used the equation curve speed drying method proposed by A. Lykov, which has the form (*Lykov A., 1968*):

$$-\frac{dW}{d\tau} = K \cdot (W - W_m) \quad (1)$$

where:

$\frac{dW}{d\tau}$  – the moisture change over time (speed drying), %/s;

$W$  – running material moisture, %;

$W_m$  – the equilibrium moisture content, %;

$K$  – drying rate (1/s), which is defined by the formula:  $K = \chi \cdot N$ ;

$\chi$  – relative drying rate, %;

$N$  – drying speed in the first period, %/s.

The integral form of equation (1) can be written:

$$\frac{W - W_m}{W_{cr} - W_m} = e^{-K \cdot (\tau - \tau_{cr})} \quad (2)$$

Having logarithmic equation (2) we get:

$$\ln\left(\frac{W - W_m}{W_{cr} - W_m}\right) = -K \cdot (\tau - \tau_{cr}) \quad (3)$$

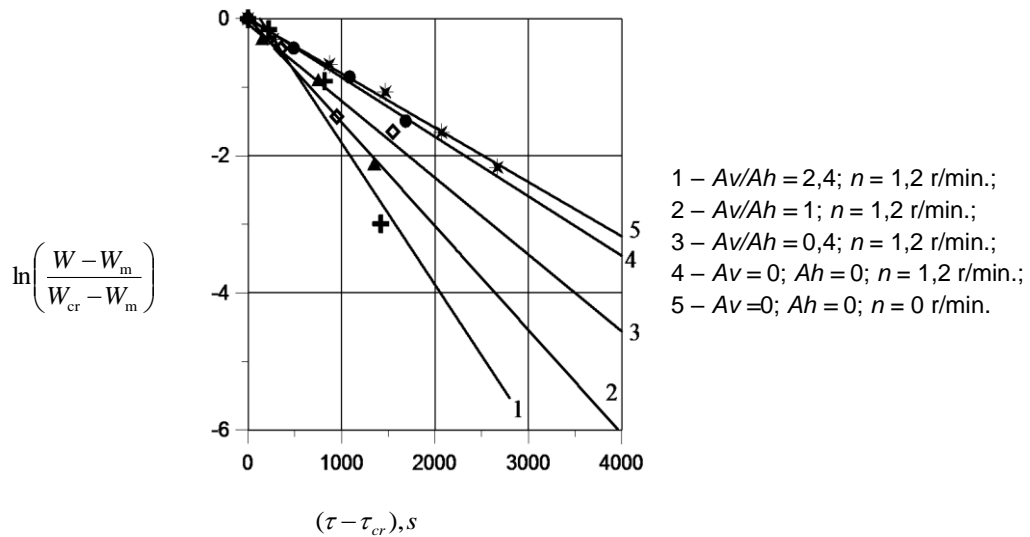
To determine the drying coefficient  $K$  for the research of kinetics vibration filtration dehydration of FPPS in the second period we built graphical dependence:  $\ln\left(\frac{W - W_m}{W_{cr} - W_m}\right) = f(\tau - \tau_{cr})$ , (fig.1-4), which are linear.

## RESULTS

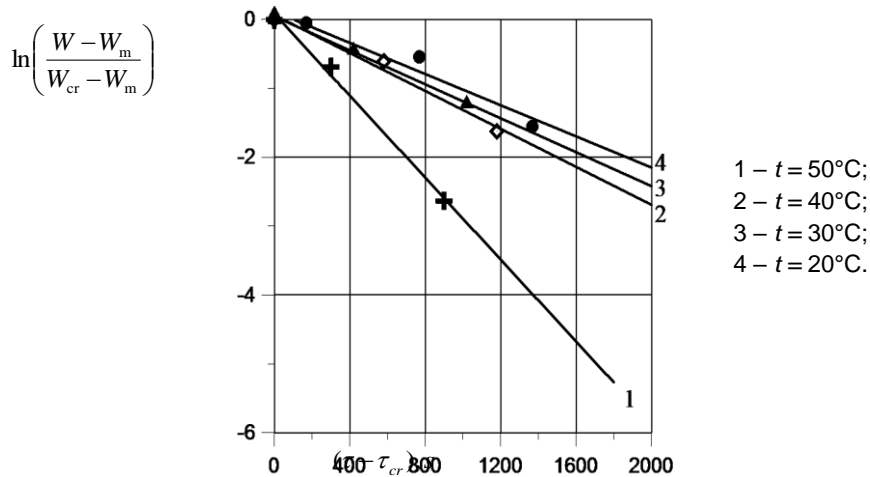
Drying factor  $K$  is defined as the slope of the line to the vertical axis (fig. 1-4). The resulting figures are presented in table 2. The coefficient drying  $K$  is not a constant (the ratio increases with the vertical and horizontal components of vibration amplitude, with increasing temperature of the coolant and reducing the height of the material) (table 2).

To determine the drying length in the first period (*Tsurkan O. et al, 2015*) we considered the graphical dependence of the critical drying time  $\tau_{cr}$  and the speed of drying  $N$  in the first period (fig. 5), according to which such an evident relationship results:

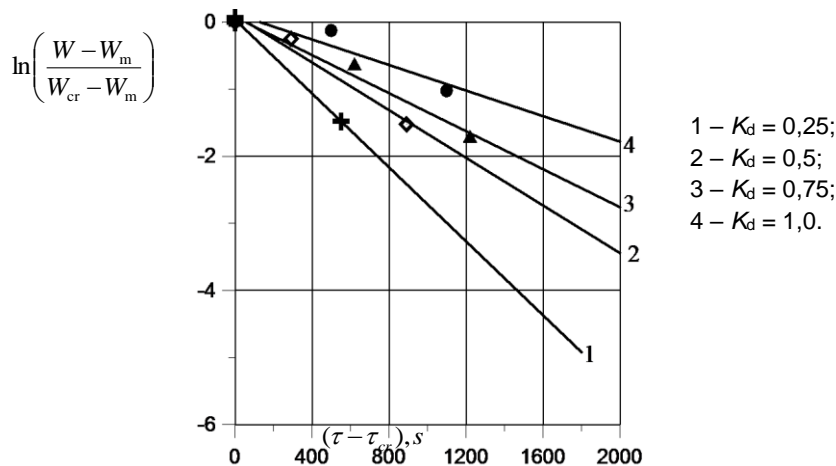
$$\tau_{cr} = \tau_1 = \frac{28,1}{N^{0,83}} \quad (4)$$



**Fig. 1 – Determination of FPPS drying K by vibration filtration dehydration at different ratio of vibration amplitude vertical and horizontal components under the following conditions:**  
 $A\omega^2 = 55$  m/s<sup>2</sup>;  $t = 30^\circ\text{C}$ ;  $K_d = 0,75$ ;  $\Delta P = 1250$  Pa



**Fig. 2 – Determination of FPPS drying K by vibration filtration dehydration at different temperature of drying agent under the following conditions:**  
 $K_d = 0,75$ ;  $\Delta P = 1250$  Pa;  $n = 1,2$  r/min.;  $A\omega^2 = 55$  m/s<sup>2</sup>;  $A_v/A_h = 2,4$



**Fig. 3 – Determination of FPPS drying K by vibration filtration dehydration at different values of the drying chamber filling circuit  $K_d$  under the following conditions:**  
 $t = 30^\circ\text{C}$ ;  $\Delta P = 1250$  Pa;  $n = 1,2$  r/min.;  $A\omega^2 = 55$  m/s<sup>2</sup>;  $A_v/A_h = 2,4$

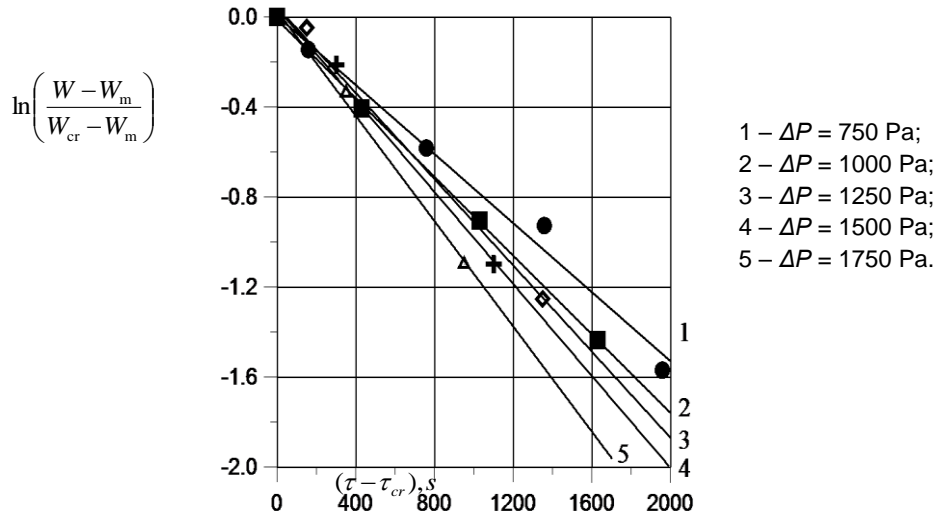


Fig. 4 – Determination of FPPS drying  $K$  by vibration filtration dehydration at different pressure drop under the following conditions:  
 $A\omega^2 = 55 \text{ m/s}^2$ ,  $t = 30^\circ\text{C}$ ;  $K_d = 0,75$ ;  $Av/Ah = 2,4$

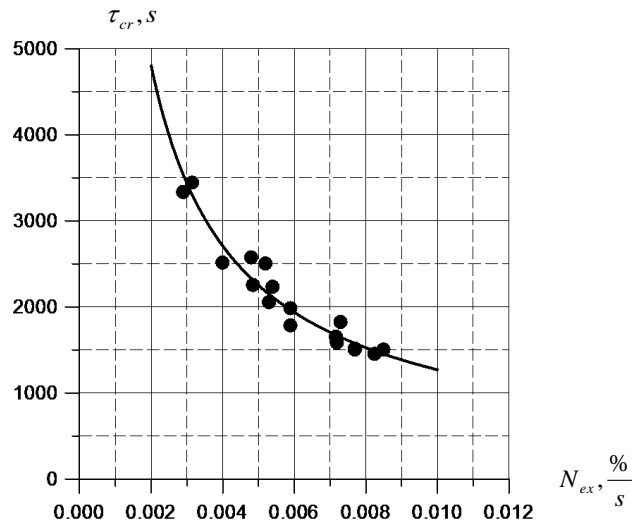


Fig. 5 – Dependence of FPPS drying ( $N$ ) in the first period on vibration filtration dehydration critical time

The calculations built graphical dependence  $K = f(N)$  (fig. 6), which is defined as the relative rate of drying slope given in the equation:

$$K = \chi \cdot N. \tag{5}$$

Relative factor is drying  $\chi = 0,157\%$ .

Equation (2) is derived to calculate humidity depending on FPPS in time to test a range of parameters for the drying process of the second period:

$$W_{II} = (W_{cr} - W_m) \cdot e^{-0,157N(\tau - \tau_{cr})} + W_m \tag{6}$$

Substituting (4) into the equation (6) we have:

$$W_{II} = (W_{cr} - W_m) \cdot e^{-0,157 \cdot N \cdot \left(\tau - \frac{28,1}{N^{0,83}}\right)} + W_m \tag{7}$$

The investigations make it possible to track mutual parameters of first and second periods of FPPS vibration-process filtration dehydration (fig. 6).

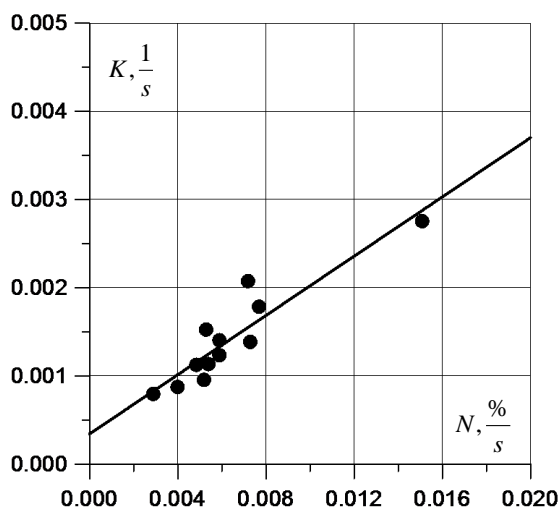


Fig. 6 – Dependence of drying K (the second period) on the rate of FPPS vibration filtration dehydration N (in the first period)

The drying time in the first period was determined by the formula (4), and the second – in the equation (7) and it is the following:

$$\tau_{II} = -\frac{1}{0,157 \cdot N} \cdot \ln\left(\frac{W - W_m}{W_{cr} - W_m}\right) \tag{8}$$

The duration of FPPS vibration filtration dehydration investigated the changes range of the process parameters is:

$$\tau_k = \tau_I + \tau_{II} = \frac{28,1}{N^{0,83}} - \frac{1}{0,157 \cdot N} \cdot \ln\left(\frac{W - W_m}{W_{cr} - W_m}\right) \tag{9}$$

This shows that the drying depends on the speed of drying N in the first period, running, and moisture equilibrium on FPPS movement.

Table 2

Determining factors of drying, depending on changing technological parameters of FPPS vibration-filtration dehydration

Process parameters				First drying period	Second drying period
t, °C	H, m	$\frac{A_v}{A_h}$	n, r/min	N, %/s	K, 1/s
30	0.026	2.4	1.2	0.0072	0.00207
		1	1.2	0.0053	0.00152
		0.4	1.2	0.00485	0.00112
		0	1.2	0.004	0.00087
		0	0	0.0029	0.00079
30	0.0075	2.4	1.2	0.0151	0.00275
	0.0175			0.0077	0.00178
	0.026			0.0059	0.0014
	0.03			0.0052	0.00095
50	0.026	2.4	1.2	0.0085	0.00297
40				0.0073	0.00138
30				0.0059	0.00123
20				0.0054	0.00113

Analysing the results of FPPS vibration filtration dehydration process of (table 2) we found that the increase in the ratio of vibration amplitude vertical and horizontal components of the drying  $\frac{A_v}{A_h}$  chamber from 0 to 2.4 by the simultaneous increase in rpm stirrer-cleaner  $n$  from 0 to 1.2 r/min. speed the drying process in the first period increases by 2.4 times.

## CONCLUSIONS

1. We determined the type of relation between moisture and the material and the corresponding interval of FPPS moisture limits reasonably rational methods of dewatering and drying constructive scheme appropriate equipment.

2. The increase of the process speed is limited by the maximum allowable temperature of FPPS heating (especially for sowing and pharmaceutical purposes), and fill coefficient of drying chamber volume is limited by compromise productivity values and specific energy equipment.

3. We summarized kinetics vibration filtration dehydration of FPPS in the second period by the method proposed by A. Lykov.

4. According to the research of kinetics vibration filtration dehydration of FPPS in the second period we built a tracker  $\ln\left(\frac{W - W_m}{W_{cr} - W_m}\right) = f(\tau - \tau_{cr})$  determined coefficient  $K$  and relative drying rate, which is  $\chi = 0.157\%$ .

5. We defined the changes of drying coefficient  $K$  in key technical parameters of the process: drying coefficient  $K$  increases with the ratio of vibration amplitude vertical and horizontal components, with increasing temperature of the coolant and reducing the height of the FPPS material.

6. We defined the dependence of calculating FPPS humidity in time to test the range change process parameters and the process of drying and its length depending on drying speed in the first period and running, and the moisture equilibrium on FPPS movement.

7. We confirmed the feasibility process of intensifying FPPS vibration filtration dehydration by increasing the ratio of vibration amplitude vertical and horizontal components of the drying chamber (in case of increase in the ratio  $\frac{A_v}{A_h}$  of 0 to 2.4 by the simultaneous increase in rpm stirrer-cleaner  $n$  from 0 to 1.2 r/min. speed the drying process in the first period increases by 2.4 times).

## REFERENCES

- [1] Atamanjuk V., (2007), Hydrodynamics and a heat mass exchange during filtrational drying of disperse materials (Гідродинаміка і тепломасообмін під час фільтраційного сушіння дисперсних матеріалів): *Author. Dis. on competition sciences. Degree dock. Sc. Science*, p.46, Lviv/Ukraine;
- [2] Atamanjuk V., Gumnytskyj Ya., (2009), Mathematical model of heat exchange process during the second period of dispersed materials drying filtration (Математична модель процесу теплообміну під час другого періоду фільтраційного сушіння дисперсних матеріалів), *The East European Journal of Advanced Technologies*, Vol.37(1/4), pp.20-24, Kharkov/Ukraine;
- [3] Нанук Я., (1992), Filtrational drying of flat permeable materials (Фильтрационная сушка плоских проницаемых материалов), *Dis.Dr.Sc. Sciences: 05.17.08*, p.426, Lviv/Ukraine;
- [4] Holubkovych A., (1986), Classification of seeds for drying (Классификация семян для сушки), *Vegetable e Farming (Овощное хозяйство)*, №. 2, pp. 33-36, Moscow/Russia;
- [5] Lykov A., (1968), Theory of drying (*Теория сушки*), p.472, Moscow/Russia;
- [6] Мукучак В., Biley P., Kindzera D., (2012), Hydrodynamics of veneer packet filtration drying (Гідродинаміка фільтраційного сушіння пакета шпону), *Scientific Journal NLTU Ukraine (Науковий вісник НЛТУ України)*, Vol. 22.5, pp. 148-154, Lviv/Ukraine;
- [7] Palamarchuk I., Tsurkan O., Hurych A., (2016), Prospects of vibromechanic combined action during processing and food production (Перспективы использования комбинированного вибромеханического действия в процессах перерабатывающих и пищевых производств), *Vibrations in Engineering and Technology*, Vol. 2(82), pp.100-108, Vinnitsa/Ukraine;



- [8] Poperechnyj A., (2007), Scientific substantiation of mechanical vibrations influence on the processes intensification of food raw materials processing (Наукове обґрунтування впливу механічних коливань на інтенсифікацію процесів переробки харчової сировини): *Author. Dis. on sciences competition. Degree dock. Sc. Science*, p.36, Kharkov/Ukraine;
- [9] Pravdjuk N., Tsurkan O., Koz I., Gerasimov O., (2011), Vibratory dryer (Вібраційна сушарка), *Patent № 64644*, Ukraine;
- [10] Рymar Т., (2009), Resource conservation in colloidal materials drying (*Ресурсозбереження під час сушіння колоїдних матеріалів*), *VSN. eng. acad. of Ukraine (Вісн. інж. акад. України)*, Vol. 1, pp. 193-196; Kyiv/Ukraine;
- [11] Stanislavchuk O., (2007), Drying of paste-like materials in a motionless layer (Сушіння пастоподібних матеріалів у нерухомому шарі): *Author. Dis. on sciences competition. Degree kand. Sc. Science*, p.22, Lviv/Ukraine;
- [12] Tsurkan O., Gerasimov O., Rymar T., Stanislavchuk O., (2014), Hydrodynamics of dehydration filtration process of fresh-peeled pumpkin seeds with vibration activation (Гідродинаміка процесу фільтраційного зневоднення свіжеочищеного насіння гарбуза з вібраційною активацією), *Vibrations in Engineering and Technology*, Vol. 2(74), pp. 138-144, Vinnitsa/Ukraine;
- [13] Tsurkan O., Gerasimov O., Polyevoda Y., Rymar T., Stanislavchuk O., (2015), Generalization of kinetics of fresh-peeled pumpkin seeds 1st period of dehydration filtration with vibration and pneumatic activation (Узагальнення кінетики 1-го періоду фільтраційного зневоднення свіжеочищеного насіння гарбуза з вібраційно-пневматичною активацією), *Journal Scientific Works of National University of Food Technologies*, Vol. 21, №. 2, pp. 151-159, Kiev/Ukraine;
- [14] Tsurkan O., Yanovych, V., Gerasimov O., (2009), Results of theoretical and experimental studies of vibratory dryer dynamics (Результати теоретичних та експериментальних досліджень динаміки руху вібраційної сушарки), *Vibrations in Engineering and Technology*, Vol. 4(56), pp. 149-156, Vinnitsa/Ukraine.