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# Description of heat exchange in the similarity theory of vibrating drying process of sunflower

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## Abstract

**Introduction.** The purpose of research is to develop a criterion equation for calculating the kinetics of drying sunflower seeds in a dryer with vibrating U-eminent container.

**Materials and methods.** The article used the basic tenets of the theory of similarity for heat and mass transfer processes, dynamics of vibration liquefied layer of loose products, methods thermo physical experiment.

**Results.** Done criterion equations in generalized variables of drying sunflower. Due to the small range of measured values and correspondingly large divergence among Stanton, Stanton define generalized numbers with different loading of the container, constructing graphs of the modified Stanton number of vibration from the vibration of the modified Péclet number.Compiled dependency can more accurately take into account the effects of vibration in the implementation of heat and mass transfer processes, including increasing the heat transfer surface, reducing the coefficient of internal friction and viscosity under dry technology environment. Last factors create favorable conditions for the potential reduction of energy consumption in transportation and cooked loose products. The effect of vibration technology is a major factor to adjust the dynamic state of the object processing, particularly in settlement system instability due to energy dissipation in the bulk mass.

**Conclusions.** This equation is recommended for calculating the kinetics of drying sunflower seeds in the range Péclet number $1.3 < Pe < 2$, for the degree of loading of the container $0,33 < \Pi < 0,67$ and with respect to temperature during grain drying and its initial value within $2,2 < T < 3,4$.

## Introduction

The purpose of research is to develop a criterion equation for calculating the kinetics of drying sunflower seeds in a dryer with vibrating U-eminent container.

In the study of various physical phenomena used two research methods that allow to obtain quantitative laws. The first method uses experimental study of the specific properties of a single phenomenon, the second - breaking theoretical study of this problem. The advantage of the experimental method of research is the reliability of the results.

## Materials and methods

Investigated materials are freshly sunflower seeds, which after drying process goes on in vegetable oil processing and deposit. Humidity during seed maturation is 15...19%, and the seeds processed – 7%.

Defining constants in the equation of criterion variables generalized process of drying sunflower seeds, based on experimental data base, which was used in the analysis of the similarity theory, statistical processing methods, theory mass transfer and mixing of granular media.

Pseudo-liquefied layer is generated in container drying (Fig. 1) due to vibration vibrations.

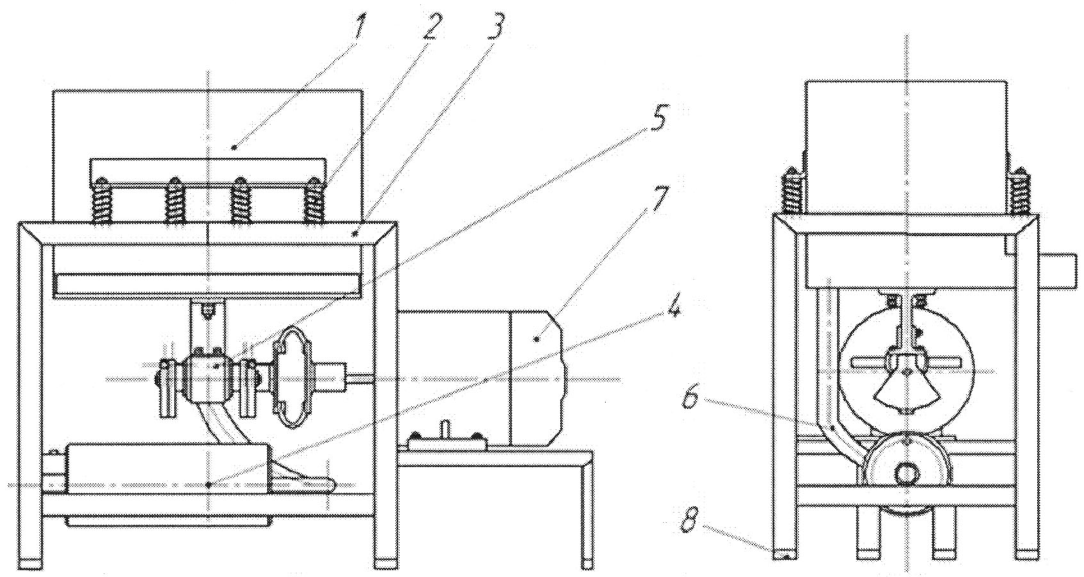


**Fig. 1. Single Container experimental vibration dryer**
1 - container; 2 - elastic suspension; 3 - frame; 4 - compressor; 5 - vibrodrive; 6 - gas pipeline pipe pipe; 7 - motor; 8 – vibrobearings.

## Results and discussion

Pseudo-liquefied layer is generated in container drying (Fig. 1) due to vibration vibrations. Therefore, we can assume that the overall situation in the hydrodynamic device (motion particles) can characterize the total average flow rate and the number that it corresponds to Reynolds number ( $Re$ ).

Therefore, the record number Reynolds should be modified, leading him to the characteristic parameters of the drying process in the vibration field.

Taking as the characteristic size of the system diameter of the machined material (seed) modified vibration (wave) Reynolds number

$$Re_B = \frac{\rho d^2}{\mu} \quad (1)$$

The relationship between convection and molecular processes of heat transfer is characterized Péclet number ($Pe$). Also, this number is the similarity criterion for convective heat transfer processes.

$$Pe_B = Re_B \cdot Sc \quad (2)$$

$$Pe_B = \frac{\rho d^2 f}{\mu} \cdot \frac{V}{D} \quad (3)$$

$$Pe_B = \frac{\rho d^2}{D} \quad (4)$$

$Sc$ – schmidt number

$$Sc = \frac{\upsilon}{D}$$

(5)

Modified vibration Stanton number - the number of similarities

$$St_B = \frac{\beta}{df} \quad (6)$$

$d$ – diameter grains;

$f$ – frequency of vibration;

$D$ – diffusion coefficient (wet-air);

$$D_0 = 0,216 \cdot 10^{-4}\ \text{м}^2/\text{с}$$

$\beta$ – mass transfer coefficient during drying

$$M = \beta F(C_H - C_\tau) \quad (7)$$

$M\left[\frac{M^3}{c}\right]$ – moisture removal during drying during the time interval

$F$ – surface area of grain;

$C_H$ – concentration of moisture in the air in terms of air saturation at;

$C_\tau$ – fluid concentrations of moisture in the air

Quest equations in generalized variables takes the form:

$$St_B = ARe_B^n \Pi^m T^k \quad (8)$$

Determination of the constants $A, n, m, k$ is based on the base of experimental data. The experiments were conducted by changing:

– production volume in the container: $\Pi$=0,67, $\Pi$=0,5 та $\Pi$=0,33

– vibration frequency $f$ =80,100 та 120 $s^{-1}$;

Dimensionless complex parametric loading is determined by the formula:

$$\Pi = \frac{V_з}{V_\Pi} \qquad (9)$$

$V_з$ – volume loading;

$V_\Pi$ – volume container.

The dimensionless temperature:

$$T = \frac{T_з}{T_\Pi} \qquad (10)$$

$T_з$ – grain temperature during drying;

$T_\Pi$ – initial grain temperature

The surface area of grain $F_{zer}$ determined by the expression:

$$F_{zer} = 4\pi R(l + 3R) \qquad (11)$$

$R$ – given radius grains

$$R = \frac{5a + 6b}{60} \qquad (12)$$

$a$ – thickness of seed, mm;

$b$ – width of seed, mm

$l$ – length of seed, mm.

Determination of the modified Péclet number vibrating carry the formula (4).

Modified vibration Péclet number when $f$ =80, 100, 120 $s^{-1}$ will be $Pe_B$ =1,3, 1,67, 2

From formula (7) ratio mass return drying:

$$\beta = \frac{M}{F(C_H - C_\tau)}$$

$M$ – moisture removal during drying during the time interval, $M^2/c$

$F$ – surface area of grain;

$C_H$ – concentration of moisture in the air in terms of air saturation at;

$C_\tau$ – fluid concentrations of moisture in the air,

$C_\tau = 13,764 \cdot 10^{-3}$

Using the i-d chart determines the value $C_H$ and tabulates. Also in the table puts the calculated values $M$ and .

Modified vibration Stanton number - the number of similarity is determined by the formula:

$$St_B = \frac{\beta}{df} \qquad (13)$$

Due to the small range of measured values and correspondingly large divergence among Stanton, Stanton define generalized numbers with different loading of the container, constructing graphs of the modified Stanton number of vibration from the vibration of the modified Péclet number. Also, we should consider only download $\Pi$=0,67 and $\Pi$=0,5. When $\Pi$=0,33 drying process is complicated because of the design of the container and the lack of grain in the container.

To determine the constants $k$ we plot the dependence modified vibrating numbers Stanton temperature loading of the logarithmic coordinate the grid.

The constants k₁ when loading the container $\Pi$=0,67 conform $k_1 = tg73^0 47^1 = 3,37$, when loading the container $\Pi$=0,5 constant $k_2 = tg70^0 = 2,82$ Mean values of constants $k_1$ та $k_2$ will correspond to the desired value $k$

$$k = (k_1 + k_2)/2 = 3,1$$

To determine the constants m summarize values $St_B / T^k$ constructing a graph of $St_B / T^k$ of the Péclet number in the logarithmic coordinate grid.

Finding data values we plot the dependence $St_B / T^k$ degree of container load $\Pi$ and find the required value of the constant $m$.

The graph we find $m = tg42^0 27^1 = 0,91$

To determine the constants $n$ and $A$ we plot the dependence $St_B / T^k \Pi^m$ of the Péclet number in the logarithmic coordinate grid.

The graph we find $n = tg37^0 2^1 = 0,76$ and $A = 97,4$

After experimental simulation of the desired equation of one sort

$$St_B = 97,4 Pe_B^{0,76} \Pi^{0,91} T^{3,1} \qquad (14)$$

Equation (4) is recommended for calculating the kinetics of drying sunflower seeds in the range 1.3< $Pe$<2, 0,33< $\Pi$ <0,67 and 2,2< $T$ <3,4.

## Conclusions

The equation is recommended for calculating the kinetics of drying sunflower seeds in the range Péclet number 1.3< $Pe$<2, for the degree of loading of the container 0,33<П<0,67 and with respect to temperature during grain drying and its initial value within 2,2<T<3,4, which makes it possible to justify operating mode settings at vibrodrying.

Implementation vibration pseudo liquid layer drying loose products enables 2.5... 3 times to reduce energy costs and create conditions for uniform distribution and heat dissipation in the mass technological environment.

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