DRYING IN VIBROBOILING LAYER - A PROMISING METHOD OF SUNFLOWER SEEDS DEHYDRATION

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AbstractIn article prospects of sunflower seeds drying are analyzed at a radiative heating, results of experimental studies on sunflower seeds drying are given in a vibrorarefied layer at a radiative heating.
Keywords: drawing, vibrorarefied layer, sunflower seeds, radiating heating.

Traditionally, in the Ukraine and Russia drying of sunflower seeds is carried out by the convective method in drum, tunnel, mine, recirculation dryers and the main advantage of which is high performance. However these dryers are quite energy intensive, large and do not provide a uniform heat treatment of seeds, because they do not take into account the specificity of sunflower seeds as an object of drying. Different chemical composition of the fruit shell (husk) and core determines varying degrees of moisture binding, which must be removed during drying. Should take into account also that the seeds of confectionary sunflower varieties husks not tight to the core, i.e. between the husk and the core has air cavity. Thus, the seed is made up of components that differ sharply on the thermodynamic properties.

More promising for sunflower seeds drying looks method of volumetric heat supply, from which in the last years, the most widely used is infrared and microwave drying method. They can provide a uniform heating of the entire seed or more intense heating of the core. In addition, there is no need to use air as a thermal agent which significantly reduces the energy consumption for the drying process. Promising in this sense looks combination of infrared and microwave heat supply and active contact of seeds and slightly heated or not heated air, which ensures, for example, pseoudoliquified layer, vibroboiling layer (VBL) or centrifugal pseoudoliquified layer. While for certain values of the operating parameters must be created such conditions of the drying process, which would support the temperature gradient from the center of the core to the husk. This, as a result, will provide the same direction of concentration and temperature of moisture diffusion.

The purpose of this paper is the study of sunflower seeds drying in VBL layer during radiative heat supply.

Modeling of heat and mass transfer when are dried seeds of sunflower requires knowledge of the physical and mechanical product characteristics, in particular, seed size, bulk density of seeds layer, surface layer, etc. Determination of some of these characteristics requires the application mathematical statistics methods, because the shape of seeds is relatively complex and cannot be accurately modeled with a simple form, which describe, for example, rapeseed (the ball).

We investigated the following characteristics of oleaginous varieties "Titanic" sunflower seeds: the linear size, shape, weight of 1000 seeds, bulk and physical density, porosity. Object of study - sample of 300 seeds with a moisture content of 19.4% of the harvest 2011. To measure the length, width and thickness of the seeds was used calipers accurate to 0.1 mm. To determine the mass of 1000 seeds, and physical bulk density, porosity we have used graduated cylinder on 200 ml with scale interval of 5 ml and electronic scale accurate to 0.01 g.

Obtained variation curves were tested for law of normal distribution, which is observed for the other varieties of sunflower seeds and pumpkin seeds [1].

For experimental variation curves were determined selective average $\bar{\tilde{o}}*$ and square average deviation σ* [2]:

$$\bar{\tilde{o}}* = \frac{\sum n_i x_i}{\ddot{i}}, \quad \sigma* = \sqrt{\frac{\sum n_i \left(x_i - \bar{x}*\right)^2}{n}}, \tag{1}$$

where x_i - average value of sub-interval corresponding to a linear size;

p_i - the frequency that is responsible i - of that average value of sub-interval;

n – volume of selection.

Calculated statistical evaluation are shown in Table 1

For certain statistical estimates are built theoretical variation curves of the normal distribution law (dashed lines in Fig. 1):

$$\ddot{i} = \frac{1}{\pi\sigma*} \mathring{a}^{-\frac{\left(\ddot{i} - \bar{\tilde{o}}*\right)^2}{2\sigma*}} \tag{2}$$

Table 1. Statistical estimates of the experimental samples of linear dimensions of sunflower seeds

Linear dimensions, mm	Selective average, mm	Selective root mean square deviation
length	10,61	0,618
width	5,19	0,335
thickness	3,30	0,469

Checking of general aggregation of sunflower seeds on law of normal distribution with a significance level of 0.05 was performed by Pearson criterion. Its critical value for the number of degrees of freedom is 7 $\chi^2_{\hat{e}\eth}(0,05;7)=14,1$ [2]. Calculated value of Pearson: $\chi^2_{\eth}$ for length 12.7, for width 6.8, for the thickness of 11.1.

That is, for all linear dimensions is performed unevenness $\chi^2_{\eth} < \chi^2_{\hat{e}\eth}$, which with 95% confidence confirms the hypothesis of the normal law of the variation curve of the linear dimensions.

For certain sample averages length *l*, width *a* and thickness *b* of seeds is possible, using the known dependence [3], to determine its surface area, volume, and form coefficient.

To determine the closeness between the linear sizes of sunflower seeds are computed the corresponding correlation coefficients [2] lengths with width of 0.360, lengths with thickness 0.204, width with thickness 0.602. The last of these shows a sufficiently close connection of the width of the seeds with thick.

Other characteristics defined by the method [4] are given in Table. 2.

Table 2. Physical and mechanical characteristics of sunflower seedsof "Titanic" oleaginous varieties

Characteristics	Value
Bulk density, kg/m^3	453,3
Physical density, kg/m^3	779,3
Weight of 1000 seeds, g	65,85
Porosity of the fixed layer	0,42

Sunflower seeds of "Titanic" varieties were used for experimental research on drying of VBL with radiative heat supply.

Studies were carried out on the stand, the concept of which is shown in Fig. 1

Were investigated change of the average moisture content and temperature of the layer of the product during drying. To measure these indices was used Wile 65 moisture meter.

According to experimental data constructed curves of drying, drying speed and temperature at different points in the product (thermograms).

In Fig. 2 the curves of drying, speed of drying and thermograms of the product depending on the heat flux density which is changed by varying supply of voltage heating elements. Analysis of the curves shows that the drying process occurs practically in two periods - the linear and the falling speed drying. The period of constant drying speed in the classical representation [5] is not available on curves because the thermograms in Fig. 3, *b* are not considering typical sloping sector.

The first critical moisture content, which separates the above-mentioned period of drying, varies depending on the value of the heat flux density from 11.6% (1569 W/m^2) to 13.6% (658 W/m^2)

Tendency of changes of the first critical moisture content indicates its reducing with increasing stiffness of the thermal action on product.

Duration of drying up to 6% moisture content, which, according to [6], provides long-term storage of seeds, varies from 24 minutes (1569 W/m^2) to 69 min (658 W/m^2). It should be noted essentially nonlinear nature of dependence of drying time on the heat flux density. For example, reducing the heat flux density from 1569 W/m^2 to 983 W/m^2 (curves 1-3 in fig. 2 a), the drying up to 6% moisture content varies from 24 minutes to 34 minutes, but with decreasing from 983 W/m^2 to 658 W/m^2 (curve 4 in fig. 2, a) - from 34 minutes to 69 minutes. This, in our opinion, confirms that the drying intensity at radiative heat supply depends not only on the density of the heat flow, but also on spectrum of IR emitters. Obviously with decreasing temperature of heating elements dominant wavelength of radiation is shifted to the worst absorption of infrared rays by products, which, together with the decrease of heat supply capacity it makes a non-linear aforementioned dependence.

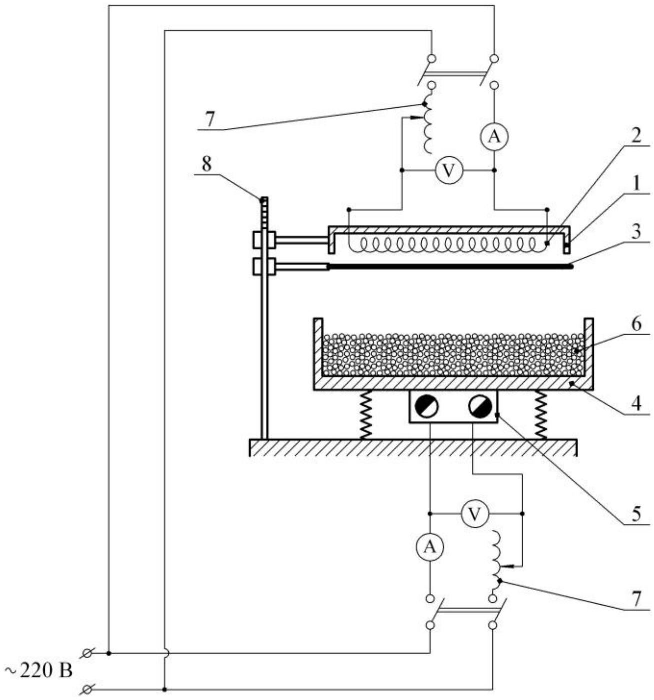

Fig. 1. Schematic diagram of the experimental stand for research of drying process of granular products in VBL with radiative heat supply: 1 – reflector, 2 - infrared emitter 3 – screen, 4 - cylindrical steel fry pan; 5 - vibrator, 6 - product; 7 - laboratory autotransformer 8 - stand for adjusting position of infrared emitters

For approximation of velocity curves in a period of falling drying velocity were used equations [5]:

$$\frac{du}{d\tau} = \chi' N\left(u - u_p\right)^n , \tag{6}$$

where $du/d\tau$ - drying speed, u - the current moisture content,

u_p - the equilibrium moisture content;

N - drying speed during the linear loss of moisture;

χ'- relative coefficient of drying;

n - coefficient, which characterizes the properties of the product.

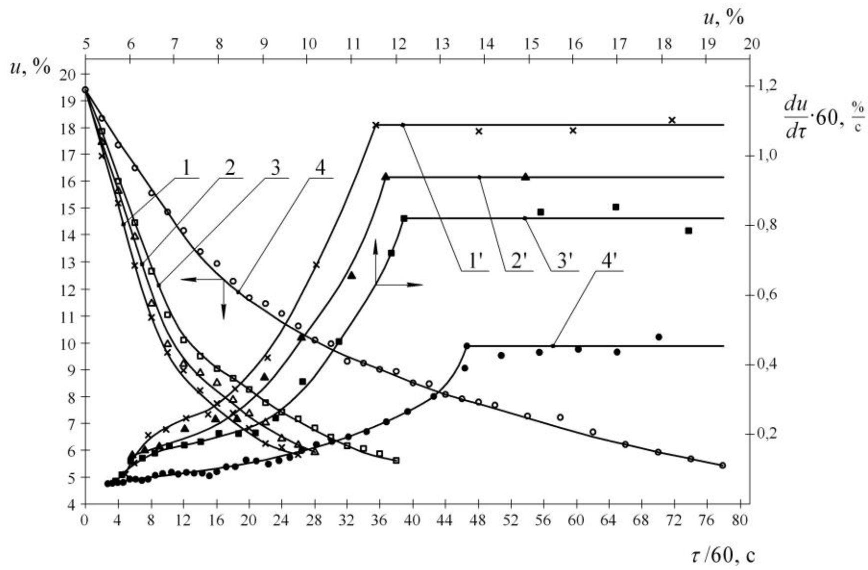

Fig. 2. Curves of drying, drying speed of sunflower seeds depending on the heat flux density: 1, 1' - 1569 W/m^2; 2, 2' - 1309 W/m^2; 3, 3 '- 983 W/m^2; 4, 4' - 658 W/m^2

Analysis of the experimental results was carried out by using least squares method in the computer package. Results are presented in Table. 3

Table 3. Data of approximation drying speed curves

Heat flux density, W/m^2	1569	1309	983	658
χ'	33,99	38,68	36,85	50,52
n	-0,546	-0,571	-0,511	-0,492
Correlation coefficient	0,999	0,999	0,998	0,995

From equation (6) by integration we get the formula for calculating drying time to final moisture content $u_к$:

$$u_k = \frac{\left(u_{кр} - u_p\right)^{1-n} - \left(u_к - u_p\right)^{1-n}}{\chi' N(1-n)} + \frac{u_0 - u_{кр}}{N}, \qquad (7)$$

where u_k - the critical moisture content, which separates the periods of linear and downward velocity of moisture remove .

Quality of the dried seeds except the final moisture content is characterized by the degree of oxidation of fatty acids of seed oil due to heat exposure during the drying process. She respectively [6], is characterized by acid number, which should not exceed 3.5 mg of KOH. A number of studies on drying show a close correlation of qualitative indicators of dried vegetable raw materials and the average temperature of the product during drying. This indicator we used for the preliminary assessment of the stiffness of the thermal regime. The average temperature of the product was determined by the thermograms in the graphical editor compass. Its value, as well as other data are given in Table. 4.

Table 4. Data on kinetics of drying of sunflower seeds depending on the heat flux density

Heat flux density, W/m^2	1569	1309	983	658
Duration of drying to a moisture content 6%, min	24	27,5	34	69
Drying speed in the first period, %/min	1,09	0,94	0,82	0,46
First critical moisture content,%	13,6	12,2	11,8	11,6
Average layer temperature, ºC	50,5	49,5	50	41,5
Maximum temperature of the layer, ºC	63,5	61,5	59,5	44

References

1. Derevinko V.V., AS Korobchenko, I. N. *Alenkina Fiziko-mehanicheskie y aerodinamicheckie charakteristiki semiyan tykvy* / Elektronij nauchnij jurnal "Proczesy i aparaty pishevyh proizvodstv." - St. Petersburg: SPbGUNiPT. - September, 2010. - Issue 2. - Mode of access: <http:// www.processes.open-mechanics.com>.

2. Gmurman V.E Teoria veroyatnostey I matematicheskaya statistika: ucheb. posobie dlya vuzov / M.: Vysh. sch., 2003. - 479 s.

3. Mishka E. P. Tehnologicheskoye oborudovanie predpriyatij proizvodstva rastitelinyh masel: ucheb. posobie dlya vuzov / - St. Petersburg: GIORD, 2001. - 368 p

4. POPERECHNYJ A. Laboratornij praktikum za kursom "Proczesy i aparaty harchiovih virobniczive" / - Donetsk: DonNUET, 2001 – 38 p.

5. Lykov A.V. Theorya sushki. - G.: Energya. - 1968. - 472 p.

6. GOST 22391-89 Sunflower. The requirements for procurement and deliveries.