Basic geometric and physical parameters of pumpkin seeds

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Abstract. The granulometric composition of Pumpkin seeds of the “Samson” variety used as feedstock for food and vegetable oils producing industry are studied. Their geometric dimensions and physical indices are obtained experimentally. Results and dependencies necessary for designing and dimensioning of drying ovens from installation for vegetable oils production are obtained.

1. Introduction
The technological processes from the food and flavour industries and the materials used in them have a strongly expressed specificity in comparison with the processes and materials from the remaining branches. Most often these materials are not isometric which imposes in measuring drying processes and installations to know such characteristics of the disperse materials as shape and dimensions of the particles, their surface, granulometric composition, density, bulk density, etc. parameters.

There are data of pumpkin seeds parameters in the literature [4, 10], but they are incomplete and refer to narrow interval of the material moisture content.

2. Purpose of this study
The purpose of this study is to obtain experimentally the geometric dimensions and the main physical parameters of pumpkin seeds, necessary for drying installations projection.

3. Materials and Methods
The object of this study was the pumpkin seeds (Cucurbita maxima) of the “Sampson F1” variety were cultivated in a field situated close to Plovdiv (Bulgaria) – harvest 2017. Pumpkin seeds have been rich in protein, glyceride oil, phytosterols and vitamins. The seeds have been a source of carotenoids, tocopherols and trace elements (K, Mg, Mn, Zn, Se, Co, Cr and Mo). Seeds have been a major product for the oil-producing industry in the production of vegetable oil after cold pressing. The resulting oil has been a high content of unsaturated fatty acids. All these qualities have determined the application of pumpkin seeds to the food industry and medicine [8, 9].

For the purpose of projection and measurement of drying equipment from installations used for essential oils production, the following characteristics were determined for the material investigated [3,7,11]:

1. Density \( \rho_M \), kg/m\(^3\) - it is the material weight in a volume unit of its own:

\[
\rho_M = \frac{m_p}{V_p},
\]

where \( m_p \) is a pumpkin seeds quantity, kg;
2. Bulk density $\rho_H$, kg/m$^3$ of the particles - density of loose bulk layer of disperse material:

The bulk density of the material has been determined in the following sequence [1, 5]:
- a definite quantity of the material has been weighed $m_p$, g;
- it has been poured down loosely in the measuring glass and the level has been equalized;
- the material volume $V$, dm$^3$ has been recorded with an accuracy of up to 0.0002 dm$^3$;
- the bulk density has been calculated by the equation:

$$ \rho_H = \frac{m_p}{V} \tag{3} $$

The measurements have been processed statistically by the method for indirectly measured values [12].

3. Mean linear dimensions. The linear dimensions of the pumpkin seeds have been determined by means of direct measurements of the three characteristic sizes of the particles - length $l$, mm; width $b$, mm; thickness $h$, mm.

The measurements have been done by means of a calliper-gauge with an accuracy of 0.1 mm, measuring the linear sizes of 100 randomly selected particles, so that a representative mean characteristics have been obtained.

The data obtained for each linear dimension have been subjected to statistical processing according to the method for directly measured values [12].

4. Average equivalent diameter $\bar{d}_e$, mm defined as the diameter of the equivalent volumetric sphere. The equivalent diameter of polydisperse material of big particles that can be counted down, could be calculated from the expression:

$$ \bar{d}_e = 3 \left( \frac{6V_{PT}}{n\pi} \right)^{\frac{1}{3}} \tag{4} $$

where: $n$ - the number of particles in the sample that should be not less than 200 [11]. When measuring the average equivalent diameter, 300 particles have been counted down at each measurement; $V_{PT}$ - total volume of the number of particles, mm$^3$.

5. Average surface $F_p$, mm$^2$ of the particles:

$$ F_p = \pi \bar{d}_e^2 \tag{5} $$

6. Average volume $V_p$, mm$^3$ of the particles:

$$ V_p = \frac{V_{PT}}{n} \tag{6} $$
7. Factor of the shape $\varphi_S$, defined as a ratio on the surface of the equal volumetric sphere and of the particle:

$$\varphi_S = 4.84 \frac{V^2}{V_p^{2/3}}$$

(7)

8. Coefficient of non-sphericity $f$ - reciprocal value of the factor of shape. It has been calculated by means of the equation [2].

$$f = 0.207 \frac{V_p}{V^{2/3}}$$

(8)

9. Dispersion $a_f$ - the surface corresponding to a volume unit from the particle:

$$a_f = \frac{6}{a_e}$$

(9)

10. Initial porosity $\varepsilon_0$ - the ratio of the pores volume in the immovable layer to the volume of the layer:

$$\varepsilon_0 = \frac{V - V_0}{V} = 1 - \frac{\rho_H}{\rho_M}$$

(10)

where $V_0$ is a pumpkin seeds volume in the layer, m$^3$.

11. Archimedes criterion:

$$Ar = \frac{g d_e^2 (\rho_M - \rho_{air})}{\nu^2 \rho_{air}}$$

(11)

where: $\rho_{air}$ - air density at $t = 20^\circ$C, kg/m$^3$;
$\nu$ - air cinematic viscosity at temperature of $20^\circ$C, m$^2$/s;
$g$ - acceleration of gravity, m/s$^2$.

The data processing from the directly measured values has been done in the following sequence [12]:
- evaluating the measurements and gross blunder removal;
- calculating the average value $\bar{x}$ and the mean square deviation $S_x$ of the measured values:

$$\bar{x} = \frac{\sum x_i}{n}$$

(12)

$$S_x = \sqrt{\frac{1}{n-1} \sum (x - x_i)^2}$$

(13)

where $x_i$ and $\bar{x}$ are respectively the values of the separate measurement and the mean arithmetical value:
- the number of measurements;
- calculating the confidential interval $\Delta x$ for the series of measurements:

$$\Delta x = t(\nu, \frac{\alpha}{2}) \frac{S_x}{\sqrt{n}}$$

(14)

where $t(\nu, \frac{\alpha}{2})$ is Student's coefficient, determined according to the degrees of freedom $\nu=n-1$ and the level of significance $\alpha$;
- calculating the relative error in the measurement:

$$\varepsilon = \frac{\Delta x}{\bar{x}} \times 100, \%$$

(15)

The data processing for the indirectly measured values was done in the following sequence [12]:
- establishment of the differential dependence of the indirectly measured value $y$, from the directly measured $x_i$:

$$S_y = \frac{\partial f (\Delta x_i)}{\partial x_i}$$

(16)

- calculating the absolute error in the measurement:
\[ y = \sqrt{\sum S_i^2} \]  
- calculating the relative error:
\[ \varepsilon = \frac{\Delta y}{y}, \text{100,} \% \]  

4. Result and Discussion

Table 1 shows the values of pumpkin seeds parameters calculated after the above formulae and methods. The pumpkin seeds density investigation depending on its moisture content \( W \) (total bases) within the limits of moisture content \( W = 0 \pm 38.6\% \) (at temperature of \( t = 20 \) °C and atmospheric pressure) showed that the dependence is a linear one (Figure 1) and can be described by means of the equation
\[ \rho_M = 458.26 + 354.23W \]  
by a correlation ratio of \( r^2=0.8536 \). Similar dependence is also obtained for bulk density (Figure 2). The obtained equation has a correlation coefficient \( r^2=0.8692 \) and has the following appearance
\[ \rho_H = 293.8 + 261.18W \]  

| Parameters                          | Moisture Content (Total Bases) of pumpkin seeds, % |
|-------------------------------------|---------------------------------------------------|
| 38.6                               | 35.0                                               |
| 26.8                               | 10.6                                               |
| 4.9                                | 0                                                  |

**Table 1**  
Physical characteristics of pumpkin seeds.
The pumpkin seeds volume investigation confirms that the variation of according to humidity its linear and can be described by means of the equation

\[ V_p = 451.42 + 418.52W \]  \hspace{1cm} (21)

by a correlation ratio of \( r^2 = 0.8207 \).
5. Conclusion

1. The basic geometric and physic parameters (density; bulk density; average linear sizes, equivalent diameter, surface and volume; factor of shape; coefficient of non-sphericity; dispersity; initial porosity and Archimedes criterion) of pumpkin seeds (*Cucurbita maxima*) of the “Sampson F1” variety, Plovdiv 2017 at atmospheric conditions and wide range of material moisture content (from 0 to 40%) have been obtained experimentally (Table 1).

2. Analytical equations describing the dependencies of the density and bulk density of the pumpkin seeds from their moisture content (total bases) for the same conditions have been obtained (Eqs. 19 and 20).

3. Analytical equation describing the dependence of the pumpkin seeds volume shrinking from their moisture content for the same conditions has been obtained. The equation confirms that the dependence between the volume shrinking and pumpkin seeds moisture content as well as other materials is a linear one (Eq. 21).

4. The results obtained could be useful at designing of drying equipment and installations for pumpkin seeds oil production.

References

[1] Bonev B and others 1989 *Practical Guidance of Physics* (HIFFI Plovdiv)
[2] Elenkov V R 1988 *Drying and Drying Equipment* (Zemizdat, Sofia)
[3] Ginzburg A 1973 *Fundamentals of the theory and technology of drying foods* (in Russ.) (Food Industry, Moscow)
[4] Hadjiiski Tz, Boiadjiev B and Rangelov P 1980 Industrial Drying of Grape Seeds. Oil - Soap Industry, *Issue of Institute of Vegetable Oils, Proteins and Washing Agents Book 1* 10
[5] Nevenkin S 1993 *Drying and drying equipment* (in Bulg.) (Engineering Sofia)
[6] Hristozov D V and others 1990 *Laboratory Guidance of Physics* (Sofia Science and Art)
[7] Likov A V 1968 *Theory of Drying* (Moscow, Energy)
[8] Mushtaev V I and Ulianov V M 1988 *Drying of Dispersive Materials* (Moscow, Chemistry)
[9] Petkova Zh Y, Antova G A and Angelova-Romova M Y 2018 Development of lipid damage of pumpkin seed oil stabilized with different antioxidants during long-term storage, *Bulgarian Chemical Communications* 50 Special Issue C 112
[10] Petkova Zh Y and Antova G A 2014 Phospholipid composition of Cucurbitaceae seed oils *Bulgarian Chemical Communications* 46 Special Issue A 100
[11] Razuvaev N I 1975 *Complex Processing of By-Products from Vine Production Industry* (Moscow, Food Industry)
[12] Sendov S H 1987 *Application of Fluidized Systems in Industry* (Sofia, Technique)
[13] Vuchkov I H and Stoianov S 1986 *Mathematical Simulation and Optimization of Technological Objects* (Sofia, Technique)