TECHNOLOGICAL PROPERTIES OF THE POWDER MADE FROM JERUSALEM ARTICHOKE OBTAINED BY THE METHOD OF DRYING WITH MIXED HEAT SUPPLY

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Abstract

Present work addresses technological properties of powder made from Jerusalem artichoke, formed by the method of drying with mixed supply of heat, compared to traditional convection. It is shown that polysaccharides in the composition of Jerusalem artichoke of MHS-drying undergo less crystallization and hence drying is carried out under milder conditions than these components during convection method. We established capacity for the dispersing of dried Jerusalem artichoke in a traditional ball mill depending on the duration, which makes it possible to obtain dried products for various technological purposes. We demonstrated a capacity to swell in the resulting powder made from Jerusalem artichoke, which predetermines the formation of advanced capillary-porous structure. Results of the tensometric method of studies revealed that the formed structure of powder made from Jerusalem artichoke of MHS-drying is characterized by small pores at temperature 50 °C and by 1.2...1.5 times larger – at 70 °C, which must be considered when they are rehydrated. We examined a complex of basic functional-technological properties of powder made from Jerusalem artichoke: coefficient of water absorption (CW), water-retaining (WRC), fat-retaining (FRC) and emulsifying capacities (EC). During mathematical processing of the results received, we obtained a conceptual model that describes a dependence of the comprehensive indicator of technological properties of powder made from Jerusalem artichoke (by the defined weight coefficients: for CW – 0.2; WRC – 0.2; FRC – 0.3; EC – 0.2) depending on the temperature of MHS-drying and dispersibility.

Keywords: Jerusalem artichoke, MHS-drying, convection drying, technological properties.

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1. Introduction

The concept of all fast service enterprises is aimed at meeting the needs of consumers at the highest level, the basic principles of which are: a consumer should not have to wait; the task for the staff at an enterprise is to make a consumer want to visit it again.

However, the products in such enterprises do not always meet the requirements of a balanced nutrition, especially under condition of limited consumption of vegetables and fruits.

Therefore there is a need to use dried vegetable and fruit raw materials, in particular powders, in the technology of culinary products. This will avoid the seasonality in their consumption, simplify operations during mechanical culinary treatment of raw materials, reduce the duration of technological preparation of meals and culinary products, extend their asortment, reduce area of warehouse and production premises.

In order to solve the set tasks, technologies of traditional food profucts employ more and more alternative vegetable raw materials, including vegetable, fruit, and fruit and berry powders, which are a concentrate of biologically active compounds.

Among the variety of alternative vegetable raw materials, special attention must be paid to the Jerusalem artichoke. This is a tuber-shaped plant that is characterized by high yields and unique chemical composition, in particular by the contents of inulin, pectin substances, cellulose, vitamins and mineral substances [1–5].

Tubers of Jerusalem artichoke contain up to 3 % of protein, 2... % of nitrogenous substances, 20 % of mineral salts, micro elements, the entire group of vitamins B, especially, B_7 (biotin), vitamin C and carotene. Protein has amino acids – lysine, histidine, arginine, tryptophan, threonine. The composition of carbohydrates includes the soluble polysaccharide inulin (16...18 % and higher), which in the body is converted into high-calorie easily digestable sugar fructose, much required in a diet of patients with diabetes, however, it does not practically contain starch. Jerusalem artichoke as a source of polysaccharides is a powerful immunomodulator, that is a product that enhances protective properties of the human organism [6, 7].

Essential substances of Jerusalem artichoke that enter the human body are actively involved in the metabolism of organs and tissues, providing recovery of metabolic changes in the myocardium perfusion, during heart rhythm irregularities, decrease in tone and damage to the blood vessels at hypertension, diabetes, reduced hemoglobin, increased thrombosis, acidity of gastric juice, etc. [5–7].

Taking the aforementioned in account, by using the method of drying with mixed heat supply (MHS-drying), we formed technological properties of dried Jerusalem artichoke with humidity not exceeding 7 % [7].

2. Materials and Methods

In order to examine technological properties of powder made from Jerusalem artichoke that is obtained by the method of MHS-drying, we determined dispersity of dried Jerusalem artichoke depending on the duration of grinding; capacity to swell; technological properties: coefficient of water absorption, water-retaining, fat-retaining and emulsifying capacities, depending on the temperature of MHS-drying and dispersibility.

As the objects of study we chose Jerusalem artichoke of convection drying in line with TU U 15.3-23913766-002:2005 as a control, and the one, obtained by MHS-drying, as an experiment. Dispersibility of the received powders was investigated by the microscopic method, swelling – by the laser granulometry, technological properties – according to the generally accepted methods. Mathematical processing of obtained results was carried out using the method of least squares.

3. Results

In order to determine technological properties of Jerusalem artichoke, which are formed by drying using the method of mixed heat supply, we chose a high-yield hybrid of the variety "Interest" with a high content of inulin. Before drying, the artichoke was washed, dried, and ground in the form of chips. MHS-drying of Jerusalem artichoke was carried out at temperature 90 °C, 70 °C and 50 °C to the resulting moisture content not exceeding 7 %.

By the kinetics of drying and absorption coefficient we defined rational parameters for drying the vegetable that are: temperature 70 °C and duration of the process 70…60 s, which is associated with a different chemical composition of vegetable raw material, original water content and its chemical composition.

At the first stage of research we defined the measure of crystal structure of the dried vegetable, obtained by MHS-drying, in comparison with the convection, using the X-ray structural analysis.

An analysis of the received diffractograms (**Fig. 1**) revealed that the samples of Jerusalem artichoke obtained both by convection drying and MHS-drying display a partially organized structure, which is typical for natural polysaccharides whose macromolecules are able to rotate the plane of polarization of light rays and form a double helix [8–12].

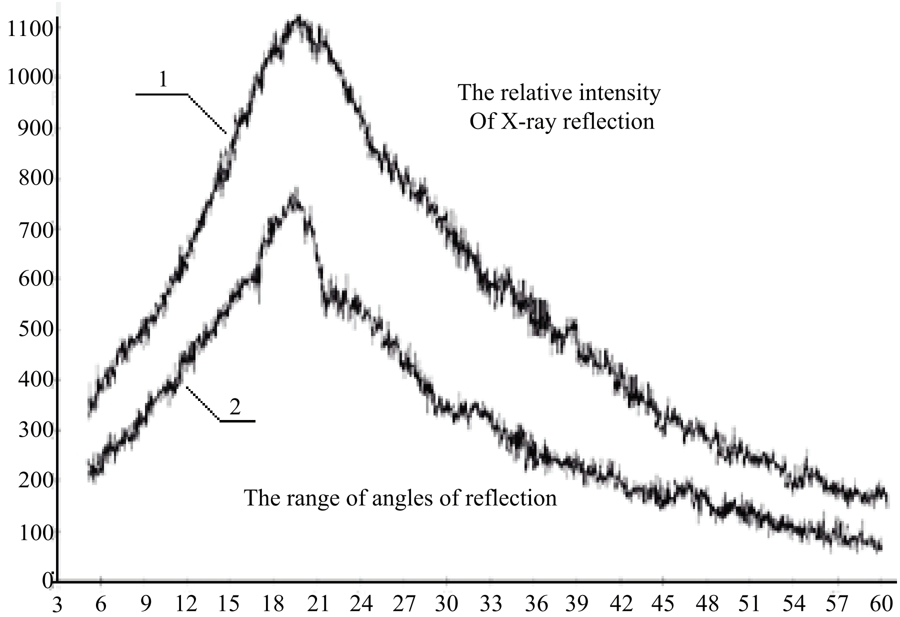


Fig. 1. Diffractograms of Jerusalem artichoke obtained by convection (1) and MHS-drying (2)

However, the sample of Jerusalem artichoke obtained by MHS-drying demonstrates a clearer diffractive reflex at angles of 2θ=20.5 against a wide blurred reflex, in contrast to the sample obtained by convection drying, where a narrow reflex manifests itself not so clearly (**Fig. 1,** curve 1).

Thus, the method of MHS-drying characterizes milder conditions of drying [7].

At the next stage, we explored technological properties of dried Jerusalem artichoke in order to predict its behavior in a number of technologies for culinary products: dispersibility, the degree of swelling, coefficient of water absorption, water-retaining, fat-retaining and emulsifying capacities.

Results of research into dispersibility of powders from Jerusalem artichoke are shown in **Fig. 2**. Particles of the vegetable powders are conditionally divided into fractions: finely-dispersed – the size of particles (10...30)·10^{-6} m, medium-dispersed – (30...50)·10^{-6} m and large-dispersed – (50...100) · 10^{-6} m.

Fig. 2 shows that the curves of distribution of particles in the powders have a distinctly pronounced peak of obtaining the large fraction during grinding for 10 s – by 81 %. At duration of grinding at 30 s, the basic fraction is of average size of the particles (30...50)×10^{-6} m – 54 %. With increasing duration of grinding, from 30 to 50 s, the dispersibility of powders (main fraction (10...30)×10^{-6} m) grows to 46 %. When prolonging the duration of grinding from 50 to 70 s, obtaining the particles of fine fraction ((10...30)×10^{-6} m) occurs by 52 %.

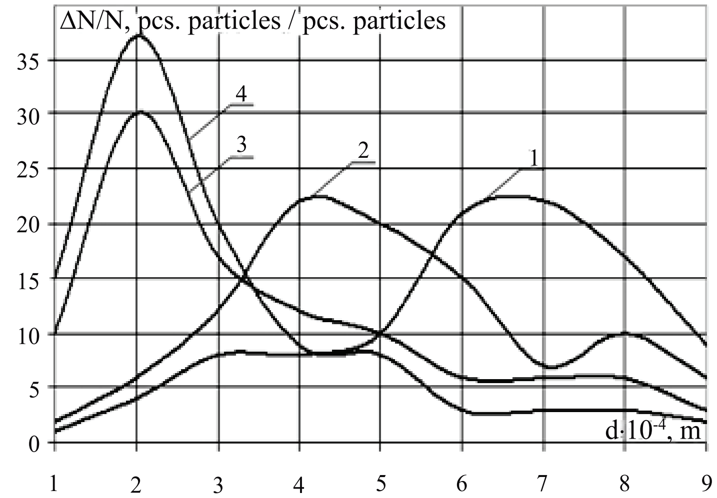


Fig. 2. Distribution of particles of powders made from Jerusalem artichoke by diameters during grinding, s: 1 – 10; 2 – 30; 3 – 50; 4 – 70

Thus, we established the ability for dispersing of dried Jerusalem artichoke depending on the duration: to obtain a large fraction, the required time is 10 s, a medium – 30 s and finely-dispersed – for Jerusalem artichoke 50 s, which is necessary to consider when receiving a vegetable powder to be used in the technological flow during preparation of culinary products at the enterprises of restaurant business.

In order to explain the manifestation of restoring properties of the powders, as well as to predict their swelling in food systems, we determined the intensity of swelling of finely dispersed powder from Jerusalem artichoke that was obtained at the temperature of MHS-drying of 70 °C.

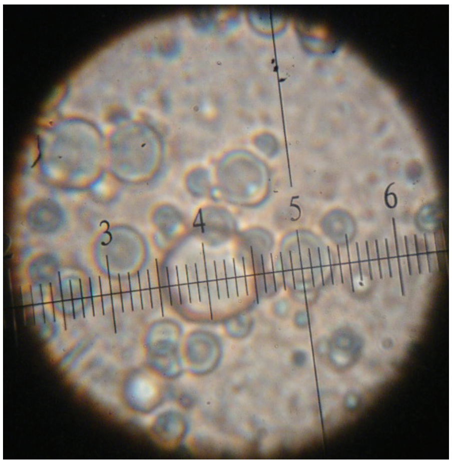
According to the methodology of research, the process of swelling in the powder made from Jerusalem artichoke with dispersibility 1...5 µm was performed in water at temperature (20 ± 2) °C during 6 hours – **Fig. 3.**

Fig. 3, *a* shows that around the surface of particles of the vegetable the solvate complexes form and the photograph clearly displays a layer of adsorption-bound moisture.

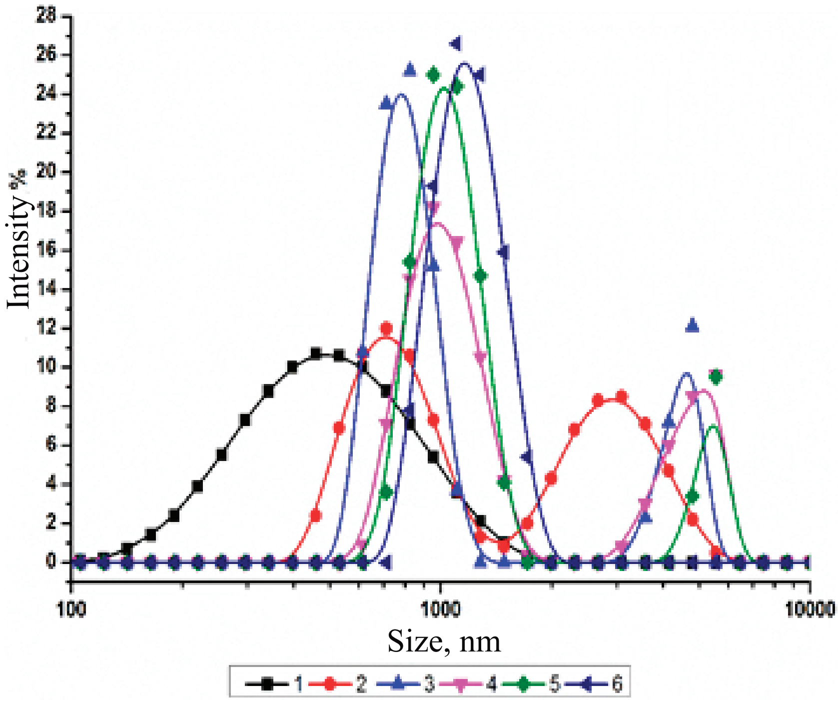
Fig. 3, *b* indicates that the samples undergo active enlargement in the size of particles of the powder made from Jerusalem artichoke in the composition of suspension. First there occurs a swelling of larger particles, then the heavy fraction of particles settles and there is an increase in the size of suspended, smaller, particles of the powder. Thus, over a period of 6 hours, the process of hydration of dried vegetable raw materials is characterized by intense swelling that is caused by high hydrophilicity of polysaccharides and capillary-porous structure of vegetable raw materials formed during drying. After 6 hours of hydration, the swelling process intensity falls and becomes a constant magnitude.

In order to substantiate the capillary-porous structure of powder made from Jerusalem artichoke, obtained by MHS-drying temperatures of 50–70 °C, we determined the size of the pores by the tensometric method.

Fig. 4 shows experimental isotherm of the sorption-desorption of powders made form Jerusalem artichoke, dried by the MHS method and the convection drying. Based on received data on the sorption properties of powders made from vegetables, we built differential distribution functions of pores in the examined vegetable powders by radii (DDFP) (**Fig. 5**). **Table 2** presents calculated parameters of DDFP for the powders made from Jerusalem artichoke. **Table 2** shows that PDFR have a fundamentally different character for the powders made form Jerusalem artichoke obtained at different temperatures. Thus, at drying temperature of 70 °C, changes in the capillary-porous structure of powder in the process of sorption-desorption are vividly pronounced, indicating the formation of artificial fine-porous structure of the powder in the process of MHS-drying – the most probable radius of capillaries is less (**Fig. 5**).



a



b

Fig. 3. Capacity to swell of the powder made from Jerusalem artichoke: *a* – microstructure of a particle in the powder (×400); *b* – intensity of swelling of particles in the powder made from Jerusalem artichoke in water during 6 hours

While at temperature of drying 50 °C, such changes are less pronounced, capillary-porous structure of the product changes differently: in the course of desorption, pore radius increases from 13.4 to 21.4×10^{-9} m, which is typical for the processes of convection drying, in which the sample undergoes shrinkage. The powder, dried at 70 °C, in the process of sorption of vapors, is restored well, the capillaries swell, which is why DFPR expands, the mean radius of capillaries is increased from 2.8 to 11.1×10^{-9} m.

The formed structure of vegetable powders during MHS-drying is characterized by small pores at temperature 50 °C and by 1.2...1.5 times larger size at 70 °C, which must be considered when dried products are rehydrated.

With regard to the concept of present study – to form the technological potential of products obtained by MHS-drying, based on the complex of conducted research, we built a mathematical model of the controlled formation of properties of dried Jerusalem artichoke: coefficient of water absorption (CW), water-retaining (WRC), fat-retaining (FRC) and emulsifying capacities (EC).

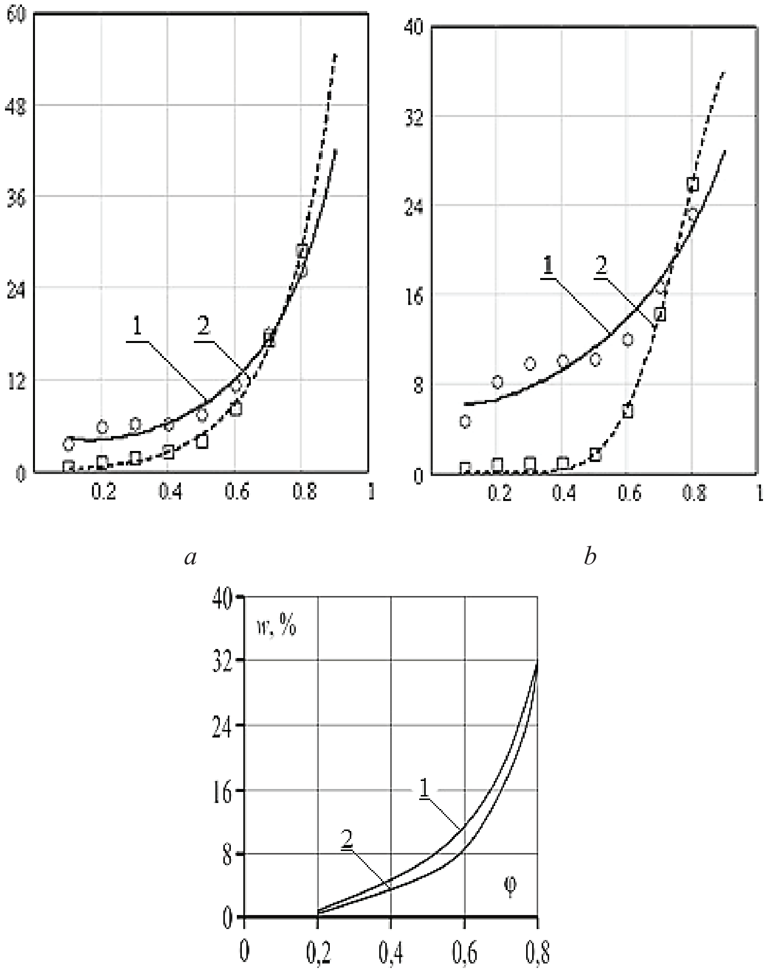


Fig. 4. The sorption-desorption isotherms of powders made from Jerusalem artichoke at temperature: *a* – 50 °C, *b* – 70 °C, *c* – MHS-drying and convection drying at 70 °C; 1 – sorption; 2 – desorption

Table 2

Parameters of the differential function of pore distribution by the radii of powders made from vegetables

Powder	Isotherm type	$R_m \times 10^{-9}$, m	$\bar{R} \times 10^{-9}$, m
Jerusalem artichoke/convection drying, 70 °C	sorption	2.51	13.4
	desorption	2.53	21.4
Jerusalem artichoke/MHS drying, 70 °C	sorption	1.00	21.1
	desorption	2.18	2.80
Jerusalem artichoke/MHS drying, 70 °C	sorption	1.33	11.1
	desorption	2.18	2.8

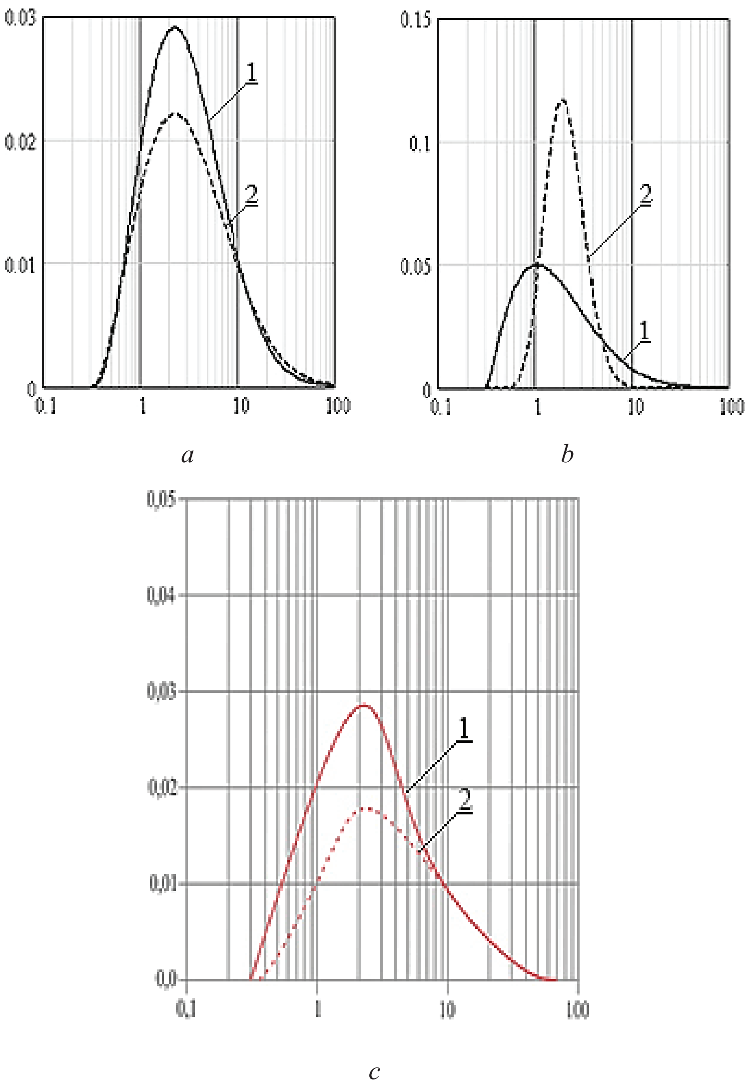


Fig. 5. Differential distribution function of pores by the radii of powders made from Jerusalem artichoke at temperature: *a* – 50 °C, *b* – 70 °C, *c* – MHS-drying and convection drying at 70 °C; 1 – sorption; 2 – desorption

At the first stage, by using the method of least squares, we compiled a regression equation and constructed a response surface by the factors of variation: x_1 – temperature of MHS-drying, x_2 is the dispersibility of powders made from Jerusalem artichoke, and by the initial parameters Y_1 – CW, relative units; Y_2 – WRC, %; Y_3 – FRC, %; Y_4 – EC, %.

At the second stage, the absolute values of the indicated technological properties were converted using a Harington scale into relative units. During mathematical processing of the results received, we obtained a conceptual model that describes the dependence of a comprehensive indicator of the technological properties of powder made from Jerusalem artichoke by the defined weight coefficients: for CW – 0.2; WRC – 0.2; FRC – 0.3; EC – 0.2.

Fig. 6 shows the response surface of a comprehensive indicator of the technological properties of powder made from Jerusalem artichoke depending on the temperature of MHS-drying and dispersibility.

We found, based on statistical data, a two-factor quadratic regression model using the method of least squares (equation 1):

$$Y=-0,853348+0,047504x_1-0,000421x_2-0,000353x_1^2+0,000007x_2^2-0,000014x_1x_2. \quad (1)$$

It is shown (**Fig. 6**) that Yмах=0.68 is achieved at the temperature of MHS-drying (65…68) °C and dispersibility up to 40 μm.

Thus, in the course of multifaceted comprehensive studies we established high technological properties of powder made from Jerusalem artichoke obtained by the method of MHS-drying, compared to the convection method.

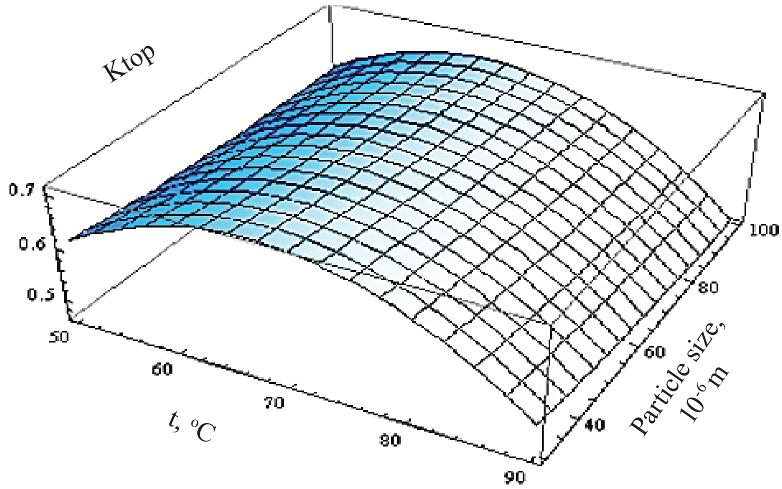


Fig. 6. Response surface of the comprehensive indicator of technological properties of powder made from Jerusalem artichoke depending on the temperature of MHS-drying and size of the particles

4. Conclusions

1. The X-ray structural examination of Jerusalem artichoke obtained by MHS-drying revealed a larger measure of crystallinity compared with the traditional convection method, which indicates sparing conditions of the new method.

2. We established a capacity for dispersing in dried Jerusalem artichoke depending on the duration of shredding.

3. A comprehensive study on the porosity in the structure of dried products was conducted. It is proved that during traditional convection drying, there occurs a significant narrowing of capillaries due to shrinkage, whereas dried products obtained by the MHS method have highly porous structure, which predetermines their higher rehydration properties.

4. A complex of research into the properties was performed, based on which we conducted mathematical modeling and optimized comprehensive indicators by the given group of properties of dried vegetables depending on the temperature of MHS-drying and the degree of dispersibility.

References

[1] Zjabliceva, N. S., Belousova, A. L., Kompancev, V. A., Popova, O. I., Kisieva, M. T. (2010). Topinambur, himicheskoe i farmakognosticheskoe issledovanija, primenenie v medicinskih i pishhevyh celjah. Pjatigorsk: Pjatigorskaja GFA, 136.

[2] Zjabliceva, N. S., Belousova, A. L., Samokish, I. I., Kompancev, V. A., Shevchenko, A. M., Kisieva, M. T. (2009). Razrabotka pishhevyh produktov i lechebnyh preparatov na osnove klubnej i travy topinambura. Pjatigorsk, 25.

[3] Poroshok topinambura mozhe tsilkom zaminyty tsukor u tisti. (2008). Khlibopekarska i kondyterska promyslovist Ukrainy, 7-8, 61–65.

[4] Korkach, H., Lebedenko, T., Sokolova, N. (2010). Vplyv poroshku topinambura na yakist khlibobulochnykh vyrobiv. Khlibopekarska i kondyterska promyslovist Ukrainy, 1 (36), 137–140.

[5] Goncharov, V. V., Vershinina, O. L., Rosljakov, Ju. F. (2013). Ispol'zovanie poroshka iz klubnej topinambura v tehnologii hlebobulochnyh i muchnyh konditerskih izdelij. Hleboprodukty, 10, 46–47.

[6] Korkach, H., Reznychenko, A. (2009). Khlibobulochni vyroby z poroshkom topinambura. Khlibopekarska i kondyterska promyslovist Ukrainy, 2, 30–32.

[7] Pogozhih, N. I. (2002). Nauchnye osnovy teorii i tehniki sushki pishhevogo syr'ja v massoobmennyh moduljah. Har'kov, 365.

[8] Belitz, H. D., Grosch, W., Schieberle, P. (2009). Food Chemistry. Springer, 1070.

[9] Cui, S. (Ed.) (2005). Food Carbohydrates: Chemistry, Physical Properties, and Applications, CRC Press, 580. doi: 10.1201/9780203485286

[10] Mazalov, L. N., Jumatov, V. D., Murahtanov, V. V., et al. (1977). Rentgenovskie spektry molekul. Novosibirsk: Nauka, 331.

[11] Shujun, W., Jinglin, Y., Wenyuan, G. (2005). Use of X-ray Diffractometry (XRD) for Identification of Fritillaria According to Geographical Origin. American Journal of Biochemistry and Biotechnology, 1 (4), 207–211. doi: 10.3844/ajbbsp.2005.207.211

[12] Cvetkov, V. N., Jeskin, V. E., Frenkel', S. Ja. (1964). Struktura makromolekul v rastvorah. Moscow: Nauka, 720.