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ДОСЛІДЖЕННЯ ОПТИМАЛЬНИХ ПАРАМЕТРІВ СУШІННЯ ПОДРІБНЕНИХ СТЕБЕЛ ТОПІНАМБУРА ДЛЯ ПОДАЛЬШОГО ПРОЦЕСУ ЕКСТРАГУВАННЯ

Наведені результати експериментальних досліджень сушіння подрібнених стебел топінамбура, які можуть бути використані як сировинний матеріал для виробництва екстрактів. Для зниження енерговитрат, запропоновано спосіб фільтраційного сушіння. Проведено вивчення особливостей кінетики і швидкості сушіння. На основі узагальнення результатів досліджень визначені оптимальні параметри для реалізації фільтраційного сушіння стебел топінамбура, що дало змогу зменшити енергозатрати на сушіння і отримати високоякісну сировину для екстрагування біологічно активних сполук. Запропоновано технологічну схему виробництва екстрактів з подрібнених стебел топінамбура.

Ключові слова: подрібнені стебла топінамбура, біологічно активні речовини, екстракція, ефективність екстракції, фільтраційне сушіння, кінетика, швидкість сушіння, оптимальні параметри, технологічна схема.

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THE INVESTIGATION OF OPTIMAL PARAMETERS DURING DRYING GRINDED ARTICHOKE STEMSFOR FURTHER EXTRACTION PROCESS

This work presents results of experimental investigations during drying grinded artichoke stems which could be used as raw material for production of extracts. To reduce power inputs the filtration method of drying is proposed. The study of kinetic and drying rate peculiarities were carried out. At thebasisofsummarizingtheresults, optimal parametersfor filtration drying of artishoke stalkshave been determined in view of reducing energy costs for drying and obtaining high quality raw material for extraction bioactive compounds. The technological scheme of the extracts production from grindedartishoke stalks has been offered.

Key words: grindedartishoke stalks, biologically active substances, extraction, extraction efficiency, filtration drying, kinetic, drying rate, optimal parameters, technological scheme.

Formulation of the problem. Plant extracts contain a significant amount of biologically active substances which can be used for the production of food products, medicines and cosmetics. Therefore, increasing the capacity of extract`s production is very important nowadays. By using various plant materials for extraction it`s possible to increase the range of natural products in Ukraine.

Jerusalem artichoke (Helianthus tuberosus L.), a species of sunflower, is widespread plant in Ukraine. The biologically active action of the artichoke is mainlydue to the phenolic acids and it has valuable medicinal properties –antioxidant, antibacterial, cholesterol-lowering, anticancer, diuretic, anti-inflammatory, antifungal and others [1, 2]. Leaves and stems represent about 60 % of the plant. Artichoke stalks are characterized by a unique chemical composition. Studies have shown that the stems of this plant accumulate mainly derivatives of mono- and di-caffeoylquinic acids, that's why can be successfully used as a raw material for extraction [3, 4]. The target components to be extracted are compounds with highantioxidant activity – polyphenols and flavonoidsand the extracts can be used for pharmaceutical and cosmetic applications, or for functional food additives [9].

The manufacturing process of liquid extracts consists of several main stages: preparation of the solvents; extraction of plant material; cleaning extract (sedimentation, filtration); standardization; packaging. Stems of artishoke have high humidity (about 60 %) and large dimensions (from two to three meters high). That`s why, grinding and drying of artishoke stems are necessary stages for further extraction process. Drying is an important process of dried material preparation for further processing because it reduces the moisture content of fresh materials for long storage and minimizes the costs of transportation and long-termpreservation. Analysis of different methods for drying the plant materials was made. The share of energy costs for drying is significant in the manufacturing lines of extracts and drying represents from 30 % to 50 % of the total costs [5]. Modern dryers are energy intensive, large and require the installation of treatment equipment [6, 7]. All these facts correspondingly increase the cost of the finished product that's why to implement the process of drying is an important task.

Analysis of recent researches and publications. Extraction involves the separation of bioactive ingredients from plant material by using selective solvents. Based on the analysis of literature sources, features of extraction from plant material and the impact of various factors on the effectiveness of the process were studied. As it is known, the extraction efficiency strongly depends on the operational conditions: size of particles, type and concentration of solvent, solid–solvent ratio, temperature, pH, contact time, etc [8]. Therefore, the extraction of bioactive substances from plants is highly influenced by size of material particles and the quality of the raw material. Drying has a great impact on the quality of raw plant materials. The presence of moisture in the cells of plant tissue blocks access to substances to be removed, lowering the efficiency of extraction in general. By drying plant materials we change the physiological state of the cell wall, making it more permeable to the diffusion of biologically active substances. However, drying conditions have significant influences on quality and stability of bioactive compounds [9 – 12]. Hotair drying can cause thermal damage and can severely modify the physical and chemical characteristics of plant materials. The effect of drying on the amount of biologically active substances of various plants, has been the subjects of numerous studies which show that the changes in the concentrations of the volatile compounds during drying depend on several factors, such as the drying method and drying conditions (temperature, air velocity, relative humidity).

The extraction of some bioactive compounds (polyphenols and flavonoids) from artichoke wastes was studied in [9]. The optimal operational conditions of extraction weredetermined in this work: solvent composition – 50 % ethanol; processing temperature 70 ^{0}C; solvent-to-solid ratio 10; processing time 30 minutes. They can be used as basic extraction process parameters necessary for development of technological schemes for production of extracts from artichoke wastes. However, there is no previous study reporting the optimal conditions for preparation of dried artichoke wastes for further extraction process.

To implement the process of drying, we propose the filtration method which can reduce power inputs in production lines. Recent studies have demonstrated that filtration drying method is energy-efficient, environmentally friendly, and economically viable for drying a wide range of disperse materialsincluding plant origin. Therefore, it is necessary to identify the optimal parameters for realization of artichoke wastes filtration drying to reduce energy costs in the production line of extracts. Optimal drying temperature should be considered because the degradation of the dried product quality occured at higher temperatures.

The aim of the work was to determine optimal parameters for preparation of dried artichoke stems for further extraction process to reduce energy costs in the production line of extracts and to obtain high quality products.

Results of the research. Raw material Jerusalem artichoke (Helianthus tuberosus L.) was purchased from a local agricultural ground in Lviv region, Ukraine. Stems of artishoke were grinded to particles from 0,08 to >5,0 mm. Results of the study size distribution of raw material are presented in Table 1.

Table 1

Particle size of grindedartishoke stems

Particle size, mm	0,08…0,16	0,16…0,315	0,315…0,63	0,63…1,25	1,25…2,5	2,5…5,0	>5,0
Fraction content, %	2,2	10,4	15,8	29,9	9,3	28,8	3,6

Actually, each particle of the grindedstemsmay be examined as a system formed by a great number of cells with intracellular space. Cell wall together with plasma membrane form semipermeable confined space of the cell containing liquid. The intracellular space is also filled by liquid.

For drying we have used coarsely ground solid matter with particle size between 0,16 to >5,0 mm. We avoided operation with very fine powder-like particles, which can create practical problems as high hydraulic resistance during filtration drying as well as difficult filtration of extracts.

Drying process was done by using filtration hot-air dryer. The study of kinetics and drying rate peculiarities during filtration drying of grinded stems were carried out at the laboratory plant. Investigationswere carried out at different temperatures and velocities of heat agent as well as different heights of the material. Drying of grindedstemsat high temperature might be unfavourable for some of the bioactive ingredients in view of their eventual thermal destruction, that`s why we have performed experiments at lower temperatures. A container with a sample was placed into a drying installation. Heat agent was filtered through the sample layer. The sample weight was measured using electronic scales. The experiments were carried out till the material weight became constant.

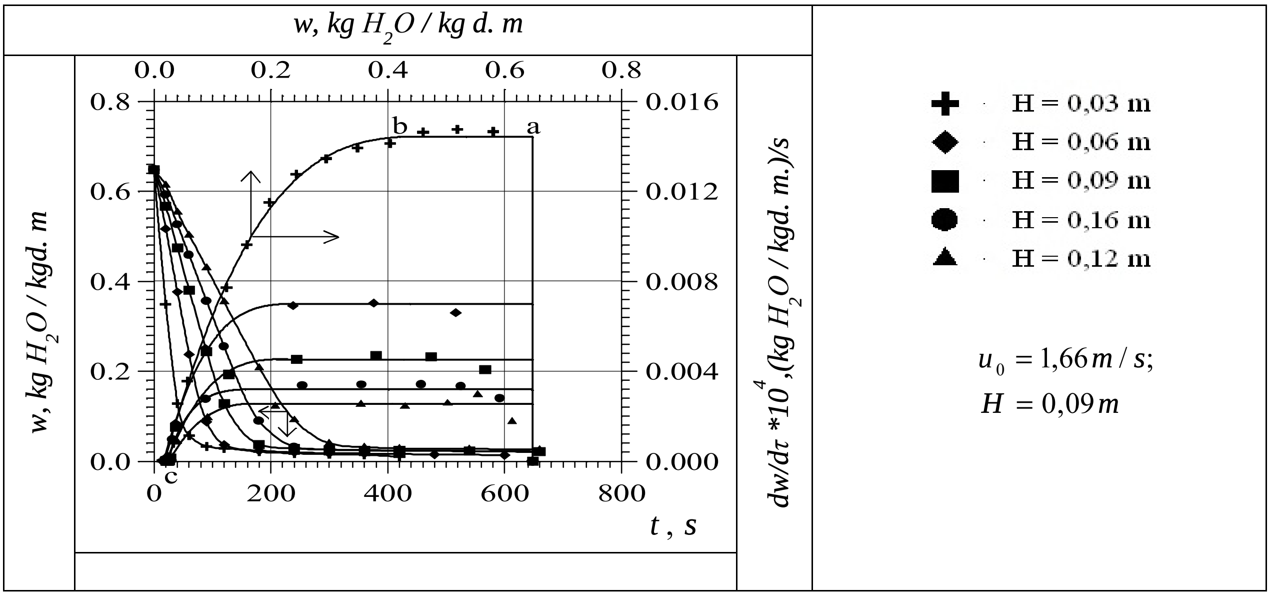

Fig. 1. Kinetic and the drying rate of artishokestems at different layer heights

A set of experiments have been performed for a temperature range from 313 to 373 K and for drying agent velocitiesfrom 0,66 to 1,68 m/s as well as heights of the materialfrom 0,03 to 0,16 m. At the beginning of the experiment the sample presented an initial moisture content of 0,67 kg H_2O /kg d. m and after drying it was 0,04 kg H_2O /kg d. m. The experimental results are represented in Figures 1 – 3.

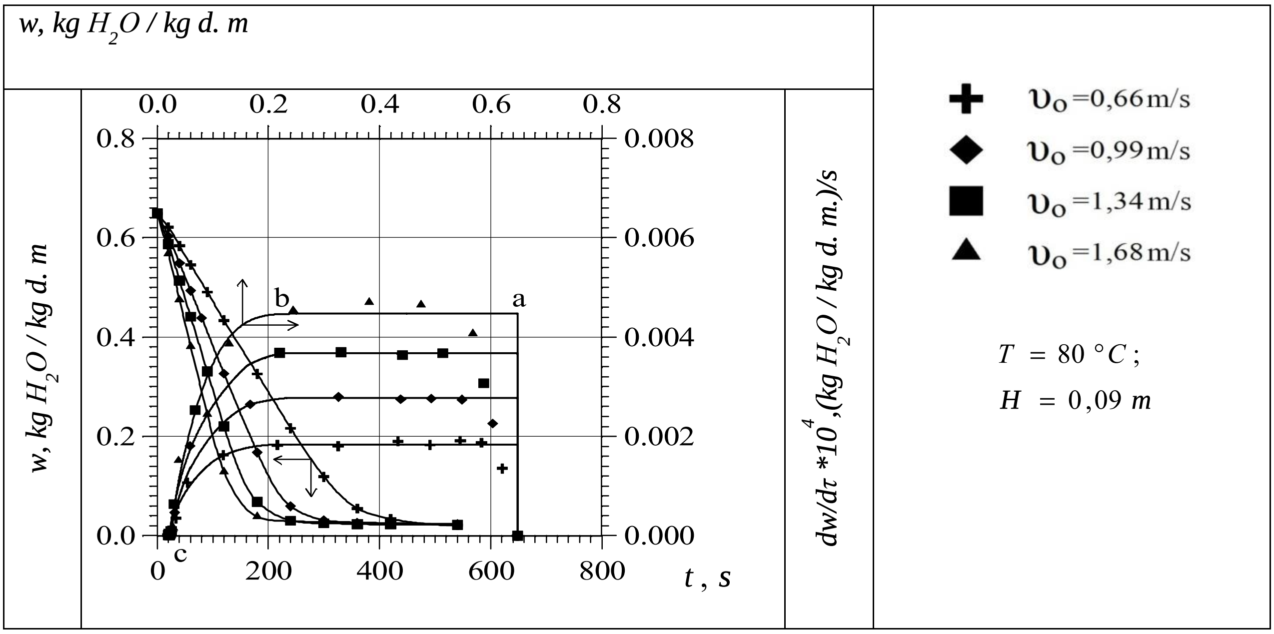

Fig. 2. Kinetic and the drying rate of artishokestems at different velocities of heat agent

It is apparent that moisture content decreases continuously with drying time. The experimental results show that, in general, higher velocity of heat agent (Fig. 2) and its temperature (Fig. 3) will intensify the drying process. The kinetic curves (Fig. 1-3) are characterized by two main periods – complete and partial saturation of the heat agent by moisture. Long period of partial saturation of the heat agent by moisture indicates the proceeding of pore-diffusion processes in the material particles which define the time of filtration drying.

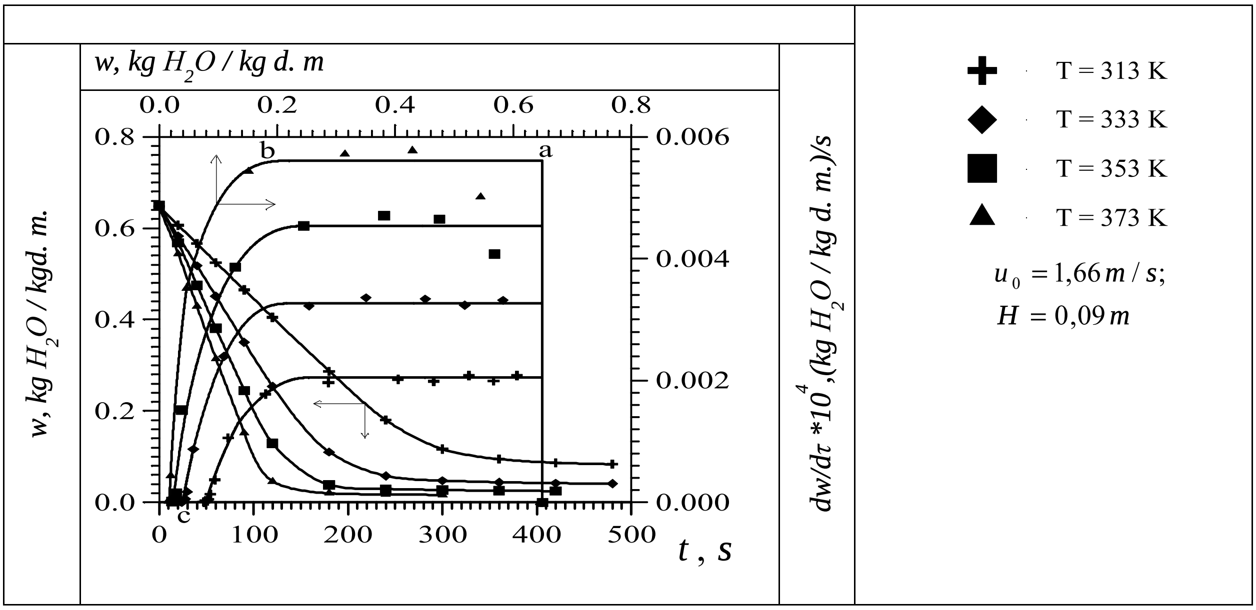

Fig. 3. Kinetic and the drying rate of artishokestems at different temperatures of heat agent

The kinetic peculiarities of grinded artishoke stems during filtration drying at four temperatures of heat agent are shown in Fig. 3. The temperature effect on effective diffusion coefficient has been examined. The diffusion process occurred during artishoke stemsdrying by filtration method has its own peculiarities and regularities provided by complex structure of the materials, interaction between their skeleton and water, shape and sizes of the pores, capillaries and particles.

The coefficients of pore diffusion from the particle centre to its surface at different temperatures were determine to predict energy consumption for drying. Then the estimated dependence of the effective diffusion coefficient on the heat agent temperature is approximated by equation:

$$D_w^t = D_w^{293} + 1.45 \cdot 10^{-9}(T - 293) \quad (1)$$

The deduced equation allows to calculate theoretically the effective diffusion coefficient for the grinded of artishokestemswithin temperature range of 313 – 373 K.

The drying rate curvesalso showthe zone mechanism of filtration drying (Fig. 1-3). The horizontal lines a-b characterize the period of complete saturation of the heat agent by moisture, which are not long, in general. The length of the horizontal lines depend on the layer height (Fig. 1). Over time, the front of the mass transfer moves in the heat agent direction and it reaches the perforated septum. At this moment saturation of the heat agent by moisturedecreases and the period of partial saturation (the vertical lines b-c) of the heat agent by moisture begine.

Accoding to the results of investigations and at thebasisofsummarizingtheresults, optimal parametersfor filtration drying of artishokestems were identified: H=0,12m; T=353K; $\upsilon_0 = 1{,}34 m/s$.

Optimal parametersfor drying implementation of artishokestemswere determined in view of reducing energy costs for drying and obtaining high quality raw material for extraction bioactive compounds (polyphenols and flavonoids), responsible for the high antioxidant capacity of the extracts. The results were directly applicable for design the technological scheme for production of extracts.

Prospective and future trends in production processes are indicating new strategies for reducing energy expenses. A wide range of technologies is available for the extraction of active components from plants, but the choice depends on the economic feasibility and suitability of the process to the particular situation. The technological scheme of the extracts production from grindedartishoke stemshas been developed and it is shown in Fig. 4.

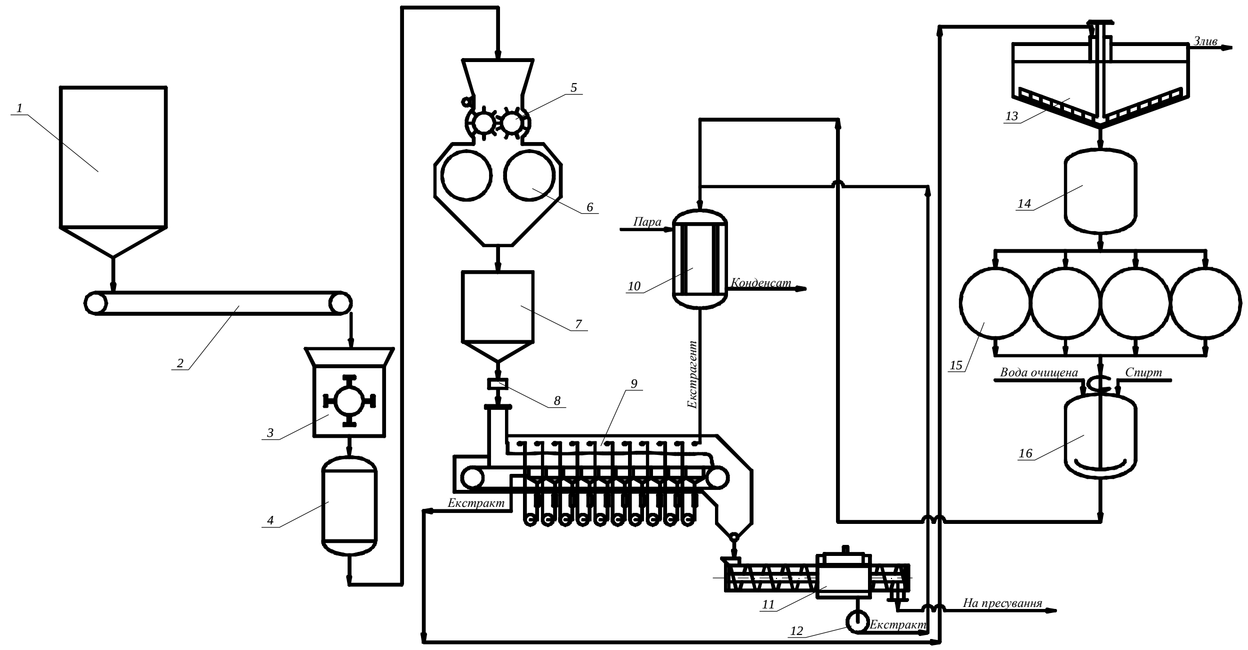

Fig. 4. The technological scheme of the extracts production from grindedartishoke stems:
1 – container; 2 – conveyor; 3 – hammer crusher; 4 – separator; 5 – dozator;
6 – filtration dryer; 7 – storage bin; 8 – dozator; 9 – belt extractor; 10 – heat exchanger; 11 – press;
12 – pump; 13 – sediment bowl; 14 –- filter; 15 – technological bins for extract; 16 – reactor

In this technological scheme the filtration method was used for drying of the raw material. The dryer worksaccording to optimal process parameters and the optimal layer of the material. The technological scheme gives us possibility to produce economically and globally competitive quality extracts from artishokestems.

Conclusions. In this work, the effect of different parameters on kinetic and drying rate during filtration drying of grinded artishokestems by using filtration drying method has been investigated. Accoding to the results of investigations and at thebasisofsummarizingtheresults, optimal parametersfor filtration drying of artishokestemshave been identified: H=0,12m; T=353К; $u_0 = 1{,}34 m/s$

The technological scheme of the extracts production from grindedartishokestemshas been developedin which the filtration dryer worksaccording to optimal process parameters and the optimal layer of material.

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