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DETERMINATION OF DRYING PARAMETERS OF JERUSALEM ARTICHOKE TUBERS

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Abstract. *A study was conducted on the dependence of the speed, duration, and kinetics of Jerusalem artichoke drying on air temperature. Rational parameters for drying Jerusalem artichoke tubers have been determined from the point of view of the maximum degree of preservation of the target component and minimum energy consumption, a stepwise processing mode in a centrifugal fluidized bed: at the first stage – the use of air with a high temperature of 110ºC, at the second stage – with a lower temperature of 75ºC, for 90·60 sec; the microwave generator power is about 1.83 kW/kg with a temperature of 79ºC, for 79·60 sec.*

Key words: *Jerusalem artichoke, stepwise drying regime, thermograms, kinetics of drying, drying curves, drying rates.*

Introduction

In recent years, Ukrainian restaurant and food industry enterprises have paid great attention to the problem of attracting new types of natural raw materials of plant origin and creating on their basis powdered semi-finished products of functional purpose, the humidity of which should not exceed 12-14%. The level of their introduction, depending on the type of meat product, is from 15% and more [1-3, 6].

Grinding of substances, including organic ones, leads to disruption of the crystalline structure of the surface layers of solids. Destruction (lattice) is accompanied by the formation of uncompensated valences on new surfaces – that is, free radicals. The role of powder products in the technology of food production is constantly increasing. This is stimulated in two ways – firstly, due to the industrialization of food production, and secondly, due to the decentralization and fragmentation of enterprises. Both of these circumstances encourage the development of the powder industry [8].

In recent years, scientists have increasingly paid attention to issues related to the expansion of the range of functional food products in restaurant establishments. Particular attention is paid to meat food products with the addition of plant raw materials. Functional food products based on plant raw materials should perform not only energy, plastic, but also regulatory functions, protect the human body from the effects of adverse factors.

Technologies for introducing food functional ingredients are shown in Fig. 1.

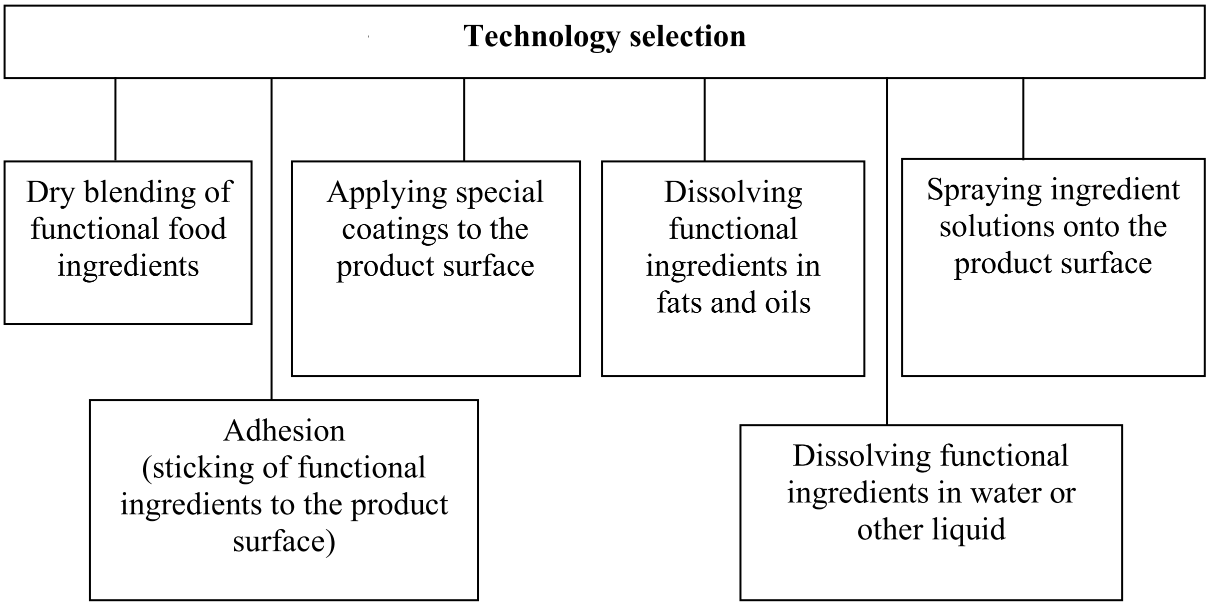

Figure 1 – Technology of introducing functional ingredients into a food product

A source: [5. 7]

Particular attention is paid to the use of Jerusalem artichoke tubers as an additive in the production of food products in catering establishments and the food industry. In this regard, our research was aimed at developing a semi-finished product in the form of a powder mixture made from plant raw materials: Jerusalem artichoke tubers and chicory root, which contain a prebiotic substance - inulin and dietary fiber, and creating culinary products using it. When using such plants as chicory root and Jerusalem artichoke tubers in food technology, which include dietary fiber – inulin, the nutritional and biological value of products increases, the level of calcium absorption increases, the water-absorbing capacity of the product, viscosity, plasticity, normal functioning of the gastrointestinal tract is maintained, their guaranteed quality during storage is ensured, that is, together with the enrichment of the product, the technological task of forming the necessary consistency and improving the functional and technological properties of products is solved.

However, the above-mentioned products considered in this section, which are made with the addition of Jerusalem artichoke, chicory root, and inulin extracted from these plants, have some disadvantages: during heat treatment, part of the inulin is lost, since it cannot withstand high temperatures, which leads to the loss of prebiotic action; obtaining inulin from Jerusalem artichoke and chicory root plants is a very laborious method, requiring high costs, which is subsequently reflected in the cost of the product; the concentrations of these plants or inulin powder do not always provide the manufactured product with a functional effect (i.e., a prebiotic effect), since the daily need for the functional ingredient is 15-50%. Thus, the use of these plants is one of the promising tasks for scientists in terms of the production of functional products that have a prebiotic effect and are recommended for implementation in restaurant establishments, especially food products made from meat raw materials, which have a predominant place and demand among consumers in our country.

Main text

The scientific literature presents experimental studies on the drying of Jerusalem artichoke tubers in a fluidized bed [5, 6], in particular, the influence of the shape and size of the cubes on the drying intensity. The studies were conducted on Jerusalem artichoke cubes with sizes (5×5×5), (6×6v6), (8×8×8), (10×10×10), (12×12×12) mm.

Analysis of the drying curves indicates that the processes of internal and external heat and mass transfer during the drying of Jerusalem artichoke tubers largely depend on the size of the product particles. Thus, when drying cubes with sizes (10×10×10) mm, the drying rate in the first period was $2.2\cdot10^{-2}$ %/sec, and with sizes (6×6×6) mm – $2.9\cdot10^{-2}$ %/sec. The size of the cubes is due to the fact that their increase to (15×15×15) mm leads to an increase in drying time, the product has a higher final moisture content within (14…15)%, reducing the cubes to (5×5×5) mm leads to product sticking to the working surface of the drum, which leads to product losses.

In experimental studies, when drying cubes of Jerusalem artichoke tubers measuring (5×5×5) mm, agglomerates of particles were formed that did not break when falling. These agglomerates began to form after the surface of the cubes dried from the beginning of the drying process.

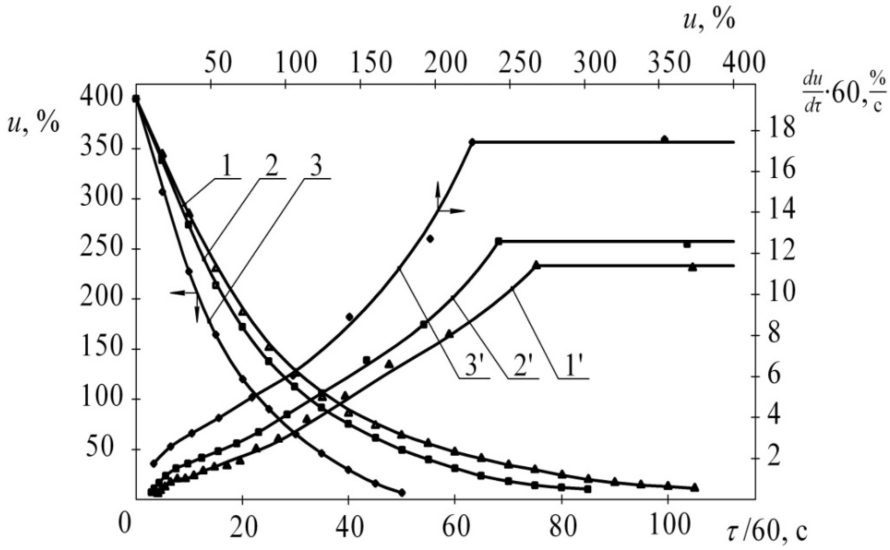

Figure 2 – Drying curves and drying rates of Jerusalem artichoke depending on air temperature: 1, 1' – 75 ºC; 2, 2' – 90 ºC; 3, 3' – 110 ºC

When the size of the cubes was increased to (10×10×10) mm, the formation of agglomerates was absent. Perhaps this is due to an increase in the balance of the weight forces of the cubes relative to the adhesion forces. Figure 2 shows the drying curves and drying rates of Jerusalem artichoke cubes (10×10×10) mm in size at different air temperatures at the inlet to the working chamber. The air speed in all experiments was 3.65 m/sec, the filling factor of the working chamber was 0.26. The air temperature in the room was 17°C, the relative humidity was 55%. As shown by the analysis of curves 1', 2', 3', the temperature increase in the center of the Jerusalem artichoke cube is very intense. The temperature head at the end of the process is: 4ºC for curve 1', 8ºC for curve 2', 12ºC for curve 3'. The air temperature significantly affects the duration of the process. When it increases from 75ºC to 105ºC, the duration of drying to equilibrium moisture content decreases by 2.3 times. At a temperature of (70…75)ºC, the drying process to a final moisture content of 12.2% lasts about 105·60 sec, while at (100…110)ºC to a final moisture content of (6…8)% – about 45·60 sec, i.e. 2.3 times faster.

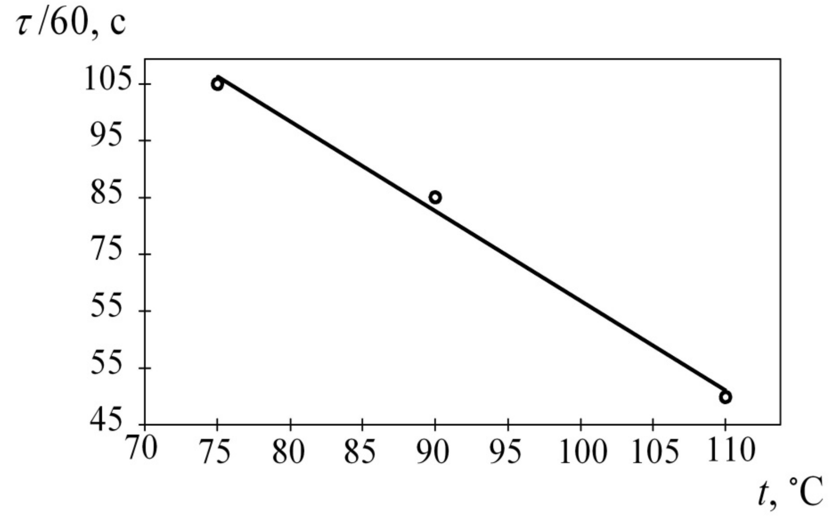

Figure 3 – Drying time depending on air temperature:
1, 1' – 75 ºC; 2, 2' – 90 ºC; 3, 3' – 110 ºC

As shown in the data shown in Figure 3, the dependence is close to linear. Analysis of the drying rate curves in Fig. 3 showed that for their mathematical description with a sufficient degree of accuracy, the model of O.V. Lykov [7] can be used, which involves replacing the actual drying rate curve in the second period with a straight line. The curve is constructed in coordinates (y-yr) – Nτ.

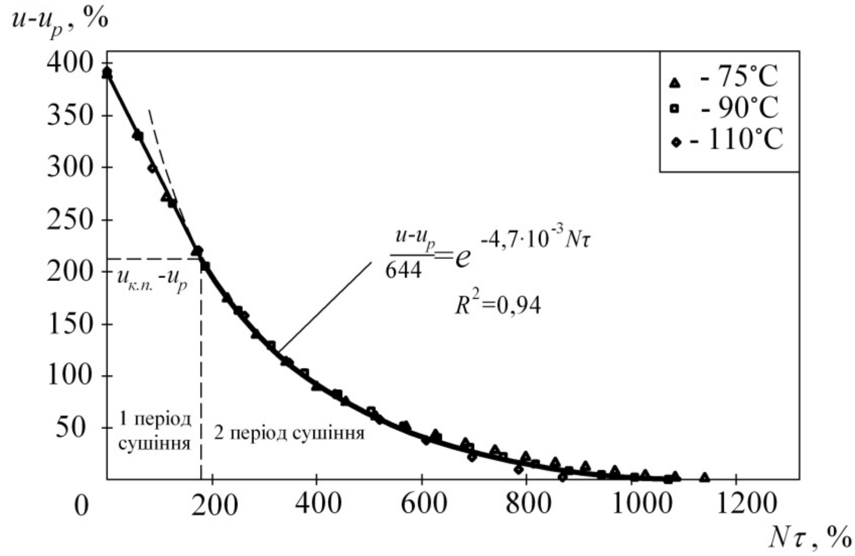

Figure 4 - Generalized drying curve

The generalizing curve is approximated by the model of O. V. Lykov using the method of least squares in the Excel program. The coefficients of the equation and %

are, respectively, the relative drying coefficient and the ordinate of the intersection point of the generalizing curve with the axis (i-ir). The values of the equilibrium moisture content ir and the drying rate of the first period N when constructing the experimental points of the curve are given in Table 1.

Table 1 - Summary table of data on the kinetics of drying of Jerusalem artichoke at different air temperatures

Indicator name	Indicator value		
Air temperature, °C	75	90	110
Equilibrium moisture content, %	12,3	9,5	6,6
Drying duration, min	105	85	50
Drying speed in the first period, %/ min	11,4	12,6	17,4
Average product temperature, °C	63,3	73	82,4

Authoring

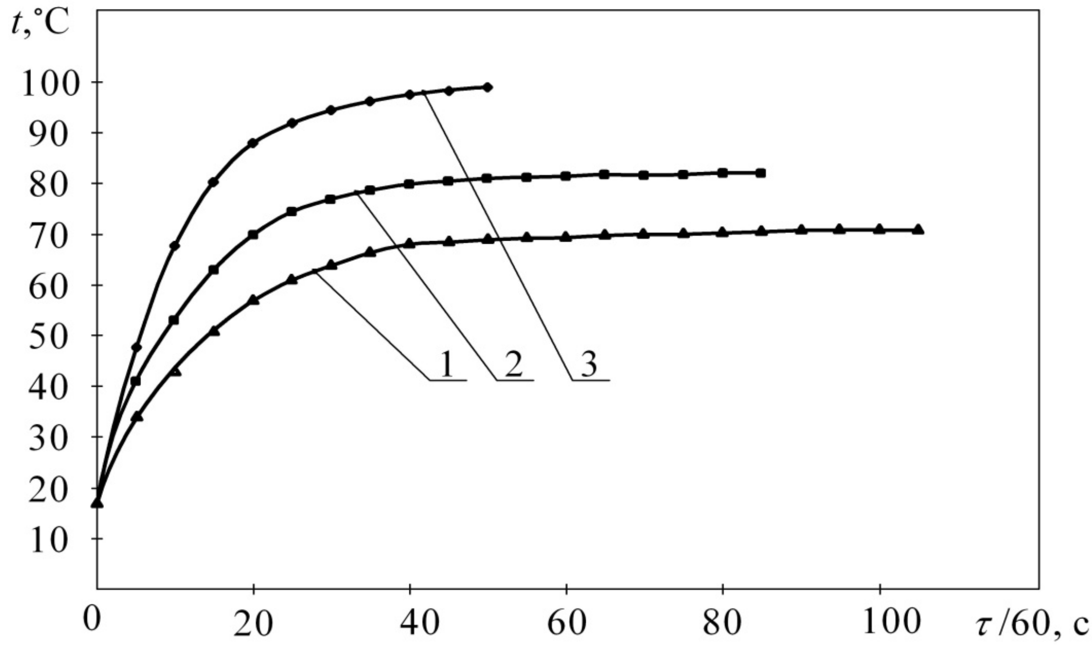

Figure 5 – Thermograms of Jerusalem artichoke cubes depending on air temperature: 1 – 75ºC; 2 – 90ºC; 3 – 110ºC

Figure 5 shows thermograms of Jerusalem artichoke cubes. They have two sections: a steep section of intense temperature increase at the beginning of the process and a flat section of almost constant temperature. The shares of each section in the overall drying process are different: as the air temperature increases, the share of the flat section decreases.

The temperature of the product during drying determines the quality of dried Jerusalem artichoke, therefore, to quantitatively assess the severity of the temperature effect of each drying mode, the average temperature of the product was determined throughout the process. For this purpose, the areas under the thermograms were determined in the AutoCAD graphic editor and divided by the duration of the process. As a number of studies have shown [8-11], the quality indicators of dried vegetables correlate well with the value of the average temperature.

Organoleptic indicators, as well as the shape of the finished product, differ significantly for different air temperatures. At air temperatures of 75 and 90ºC, significant shrinkage of Jerusalem artichoke cubes occurs during drying. They lose their original shape: the centers of the faces shift to the center of the particle. At an air temperature of 110ºC, the initial shape of the Jerusalem artichoke cubes does not change (except for the general decrease in the volume of the cube), which indicates the volumetric nature of moisture evaporation, due to the high temperature of the coolant.

The color of the finished product changes from slightly yellow (at an air temperature of 75ºC) to light brown (at an air temperature of 110ºC). Cubes dried at a temperature of 110ºC are hard, brittle and easily ground into powder, while Jerusalem artichoke particles dried at temperatures of 75ºC and 90ºC are viscous and poorly ground due to sticking to the working body of the grinder. The taste in all cases is sweet, characteristic of this product.

The color and structure of the finished product indicate a different degree of completion of the caramelization and melanoide formation reactions, due to different temperatures of the coolant. The light brown color and corresponding structure for Jerusalem artichoke cubes dried at a temperature of 110ºC indicate deeper changes in the carbohydrate complex. Therefore, such an air temperature leads to the loss of the target component of Jerusalem artichoke – inulin. On the other hand, drying at lower temperatures can lead to a significant increase in the duration of the process, which can increase energy consumption.

Therefore, a rational drying mode from the point of view of the maximum degree of preservation of the target component and minimum energy consumption is a stepwise processing mode, which in the first stage involves the use of air with a high temperature of 110ºC, in the second stage – with a lower temperature of 75ºC. The duration of the first stage for cubes of size (10×10×10) mm can be determined by the temperature curve 3' – this is the moment when the temperature in the center of the particle reaches 65ºC. This occurs 14·60 sec after the start of the process.

Figure 6 shows the drying curves 1, the temperature in the center of the Jerusalem artichoke cube 2 and the air temperature at the entrance to the working chamber 3 in the above-mentioned stepwise drying mode.

According to Figure 6, it was determined that the air temperature after 14·60 sec was sharply reduced to 45ºC in order to prevent overheating of the product, and then increased to 75ºC in order to reduce the moisture content.

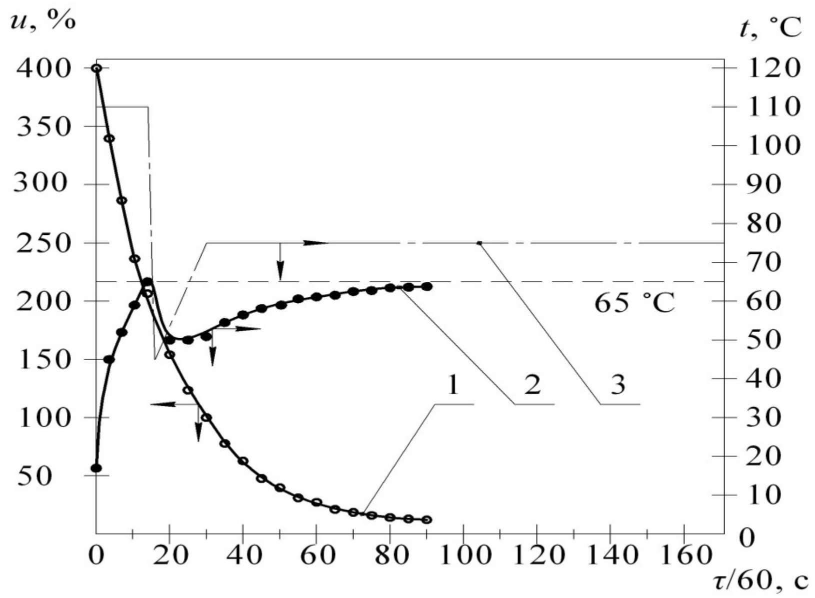

Figure 6 - Stepwise drying regime for Jerusalem artichoke tubers

Analysis of curve 2 indicates that the applied stepwise temperature regime ensured that the temperature in the middle of the cubes was below 65°C throughout the process. The drying duration was about 90·60 sec.

Summary and conclusions.

Rational parameters for drying Jerusalem artichoke tubers have been determined from the point of view of the maximum degree of preservation of the target component and minimum energy consumption, a stepwise processing mode in a centrifugal fluidized bed: at the first stage – the use of air with a high temperature of 110ºC, at the second stage – with a lower temperature of 75ºC, for 90·60 sec; for chicory root, the microwave generator power is about 1.83 kW/kg with a temperature of 79ºC, for 79·60 sec.

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Анотація. *Проведено дослідження залежності швидкості, тривалості та кінетики сушіння топінамбуру в залежності від температури повітря. Визначено раціональні параметри сушіння бульб топінамбура з точки зору максимального ступеня збереження цільового компонента та мінімальних енерговитрат, ступінчастий режим обробки у відцентровому псевдозрідженому шарі: на першому етапі – використання повітря з високою температурою 110ºС, на другому етапі – з нижчою температурою 75ºС, протягом 90·60 с; потужність генератора мікрохвиль становить близько 1,83 кВт/кг з температурою 79ºС, протягом 79·60 с.*

Ключові слова: *топінамбур, ступінчастий режим сушіння, термограми, кінетика сушіння, криві сушіння, швидкості сушіння..*

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