Technical science and innovation

Volume 2022 | Issue 1 Article 3

4-15-2022

DETERMINATION OF THE HEATING TIME CONSTANT FOR ROOT CROPS

Z K. Ergasheva
Tashkent State Technical University named after Islam Karimov, mr.aaa_93@mail.ru

Beraat Ozcelik
Istanbul Technical University

Recommended Citation
Ergasheva, Z K. and Ozcelik, Beraat (2022) "DETERMINATION OF THE HEATING TIME CONSTANT FOR ROOT CROPS," *Technical science and innovation*: Vol. 2022: Iss. 1, Article 3.
DOI: https://doi.org/10.51346/tstu-01.22.1-77-0155
Available at: https://btstu.researchcommons.org/journal/vol2022/iss1/3

14. I.Z. Chernin. *“Epoxy polymers and compositions”*.**1982**. 231.
15. H. Wang, M. Jiang, F. Sun, S. Li, C. Hse, C. Jin. Screening, Synthesis, and QSAR Research on Cinnamaldehyde-Amino Acid Schiff Base Compounds as Antibacterial Agents. “*Molecules”* **2018**. 3027.
16. A.I. Ismailov, B.A. Abidov, A.S. Rafikov. Modification of element-containing furan compounds with epoxy oligomers. “*Bulletin of Tashkent State Technical University”*. **2006**. 105.
17. A.I. Ismailov, A.S. Rafikov, M.A. Askarov. Colloidal-chemical properties of the surfactant epichlorohydrin with diethylaminofurylsilane. *“Uzbek. chemical journal”.* **2009**. 9-12.
18. A.I. Ismailov, B.A. Abidov, A.S. Rafikov. Mathematical modeling of the synthesis of furan-epoxy compounds and the study of their properties. *“Chemical technology. Control and management”*. **2006**. 17.

DETERMINATION OF THE HEATING TIME CONSTANT FOR ROOT CROPS

Z.K. Ergasheva[1], B. Ozcelik[2]
[1]Tashkent State Technical University
University St.,2 100095, Tashkent city, Republic of Uzbekistan
[2]Istanbul Technical University, 34469 Maslak, Istanbul city, Republic of Turkey

Abstract: *Convective drying refers to one of the energy-intensive processes used in chemical, woodworking, food and other industries. Therefore, in modern conditions, when there is a growing shortage and an increase in energy tariffs, it is important to develop and apply new effective methods of drying wet materials in industrial production, create high-performance drying equipment, improve the operation of existing dryers, which will contribute to the rational use of natural resources, reduce the cost of finished products and increase the competitiveness of production. Root crops are plants in which nutrients are concentrated in tubers or roots. Jerusalem artichoke refers to sugar-containing tubers, and beets, carrots, turnips, turnips, rutabagas, parsnips and couscous belong to root crops. These products are widely used for human and animal nutrition. Long-term storage of root crops in raw form requires large energy costs to maintain optimal temperature, humidity, gas composition in the storage and some other parameters. Even when maintaining optimal storage parameters, part of the crop spoils, and the other part loses its biologically active substances due to the natural processes of vital activity occurring in root crops. There are quite a few ways to store root crops. The high content of water and carbohydrates in root crops makes it difficult to preserve them. The cells of roots and tubers breathe during storage; enzymatic processes do not stop in them. With an increase in temperature and humidity of the air, the intensity of respiration increases, the loss of organic substances and vitamins increases.*

Keywords*:* *root crop, heating, temperature, tuber, drying agent, heat transfer, heat exchange, drying.*

INTRODUCTION. Vegetable raw materials, which include root crops, have a colloidal, capillary - porous structure, with fragments of high-molecular carbohydrates, protein substances, lipids, vitamins, macro - and microelements. Preparation of vegetables for drying and the process of traditional dehydration of the product itself can lead to a significant loss of biologically active substances. In this regard, the task of improving the method of drying vegetables with maximum preservation of physiologically valuable raw materials is very relevant.

Convective drying is the most common method of dehydration of vegetable raw materials in order to extend its shelf life. The convective drying method in the traditional version provides for the transfer of heat to the dried raw materials using hot air. During the transfer of thermal energy, moisture is released from the raw material, which is carried away from the installation by a drying agent.

Summarizing the literature data and experimental studies on the assessment of the thermal conductivity of vegetables, S.A. Ilenia was able to determine the thermal conductivity coefficients of a number of vegetables [5]. To date, the range of applications of carrots, beets and jerusalem artichoke is so large that it is difficult to single out all their positive qualities as fodder crops for animals and poultry, food for humans, raw materials for a wide range of food and medicines and technical products.

MATERIAL AND METHODS. The heating time constant is one of the important parameters of rootstock, which is used to determine the heating rate and select the effective IR control modes. This value is one of the determinants of the rootstock heating rate. The physical meaning of the heating time constant is explained by the following definition. The heating time constant is the time during which the excess temperature of the root crop would reach a steady-state value if there were no heat transfer to the environment. Since the drying process takes place in a closed chamber and there is practically no heat loss to the environment, the heating time constant becomes decisive for the selection of the infrared energy supply mode. The heating time constant is a characteristic;

$$T_h = \frac{C}{Q_{pr}} \tag{1}$$

here *C* - heat capacity of the product, J/°C; $Q_{пр}$ - heat output of the product, J/°C-s.

In the presence of heat transfer for a time equal to the heating time constant, the excess temperature of the product reaches a value equal to 0,632 of the steady state [1]. The heat capacity of the material depends on the heat capacity of dry matter and water. The specific heat capacity of dry matter of plant raw materials lies in the range of 0,733-1,55 J/(kg-°C). Due to the fact that the heat capacity of water *C* = 4,1868-103 J/(kg-°C) is much higher than the heat capacity of dry matter, the heat capacity of root crops during drying decreases. The heat capacity of wet materials will be determined from the expression:

$$C_M = \frac{C_{D.S.} \cdot (100-\omega) + C_{H_2O} \cdot \omega}{100} = \frac{C_{D.S.} \cdot 100 + C_{H_2O} \cdot U}{100 + U} \tag{2}$$

where $C_{D.S.}$ and C_{H_2O} is the heat capacity of dry matter and water respectively, J/(kg·°C); ω and *U* are the moisture content and moisture content of the material respectively, %. Equation (2) indicates the linear nature of the dependence of heat capacity on moisture and moisture content of the material. As the temperature of the material increases, the heat capacity increases. Equation (1) can be represented in the following form

$$T_h = \frac{C}{Q_{pr}} = \frac{c \cdot M}{\alpha \cdot F} \tag{3}$$

where c – is the specific heat capacity of root crops, J/kg·C; *M is the* mass of root crops, kg; α is the heat transfer coefficient of root crops, J/m··C·c^2; *F* is the area of the outer surface of the product, m^2. Similarity theory states that all physical processes can be described by a combination of certain dimensionless quantities (criteria) and indicates methods for finding these criteria.

On the basis of similarity theory, it is possible to simulate approximately heat and mass transfer processes [6]. Universal equation for determining the convective heat transfer coefficient, suitable for any method of heat input to the material, covering the entire drying process [8]

$$N_u = A \cdot Re^n \cdot K^m \cdot Q^R \cdot \left(\frac{\omega}{\omega_k}\right)^{\sigma} \cdot \left(\frac{P}{P_\sigma}\right)^{\lambda} \tag{4}$$

where Nu - Nussle criterion of convective heat transfer, characterizing intensity of heat exchange processes between material and drying agent; A - constant; Re - Reynolds criterion, characterizing hydrodynamic conditions of the process; K - modified Guchman criterion, determining increase of heat transfer coefficient due to tribalization of air flow by steam, formed at material surface; QR - parametric criterion determining an increase in the heat transfer coefficient due to a decrease in the thickness of the boundary layer with an increase in surface temperature during radiation drying; ω/ω_k - a parametric criterion that takes into account a decrease in the heat transfer coefficient with a decrease in the moisture content of the material at a falling drying rate; P/P_σ - a criterion that takes into account the conditions of heat exchange and mass transfer during vacuum drying of materials; ω - moisture content of the material during the drying rate decrease; ω_K - critical humidity of the material; P - ambient pressure in the chamber, kPa; P_σ - barometric pressure, kPa. Nusselt's criterion for convective heat transfer:

$$N_u = \frac{\alpha \cdot l}{\lambda} \tag{5}$$

where α - is the heat transfer coefficient, W/(m^2·°C); l - is the defining size of the evaporation surface, m; λ - is the thermal conductivity coefficient, W/(m·°C).

Reynolds criterion:

$$Re = \frac{V_{D.A.} \cdot l}{v} \tag{6}$$

where $V_{D.A.}$ - velocity of the drying agent, m/s; v - kinematic viscosity coefficient, m/s^2;

A modified Guchman criterion:

$$K = \frac{T_D}{T_W} \tag{7}$$

where T_D - is the temperature of the drying agent, °K; T_W - is the temperature of the wet thermometer, °K.

Parametric criterion:

$$Q = \frac{T_R}{T_D} \tag{8}$$

where T_R - is the radiation temperature, °K.

In dryers for vegetable raw materials the drying process takes place at atmospheric pressure. Then $P = P_\sigma$ and the criterion $P/P_\sigma = 1$.

$$\alpha = \frac{N_u \cdot \lambda}{l} \qquad (9)$$

The heat transfer coefficient characterizes the intensity of heat input, which is very important for accelerating the drying process. The obtained value of heat transfer coefficient refers to 1 m^2 of material surface - W/(cm^2·°C). It is much more convenient to use volumetric heat transfer coefficient referred to 1 m^3 of dryer volume:

$$\alpha_v = \alpha \cdot \frac{F}{V} \qquad (10)$$

Table 1

Heating time constant for root crops

Material	Moisture content w, %	Generalized indicator V/F 10^{-3}, m	time constant T, s
Carrots	10	0,7-2,6	56-262
	20		61-281
	30		68-313
	40		74-344
	50		82-378
	60		89-412
	70		98-452
	80		118-547
Topinambur	10	0,7-2,6	73-316
	20		81-352
	30		89-387
	40		97-422
	50		105-457
	60		114-492
	70		122-527
	80		130-562
Beets	10	0,7-2,6	52-190
	20		61-222
	30		69-254
	40		78-286
	50		86-318
	60		96-350
	70		104-382
	80		113-414

where F - area of the material, m^2; V - volume of dryer, m^3. Substituting (8) into (9) we get

$$\alpha_v = \frac{N_U \cdot \lambda \cdot F}{l \cdot V} \qquad (11)$$

For practical engineering calculations, drying speed and temperature curves obtained experimentally are used. The mass of the product can be represented as:

$$M = \rho \cdot V \qquad (12)$$

where ρ - product density, kg/m^3; *V* - product volume, m^3. Then the equation for the heating time constant can be represented as

$$T_h = \frac{c \cdot \rho}{\alpha} \cdot \frac{V}{F} \tag{13}$$

Denote the ratio *V/F* by the parameterσ , then the expression for the heating time constant is written as follows. In its essence, itσ is a generalized indicator of the geometric characteristic of the product. This indicator, as follows from the above, is determined by the geometric dimensions of the product.

RESULTS AND DISCUSSION. Using the above methodology, it was possible to calculate the constant heating time for root crops depending on their moisture content and size on the example of carrots, beets and topinambur. The shape of the root vegetables, sliced on an industrial vegetable slicer, takes the form of a rectangular parallelepiped. The calculated data are given in Table 2, in which *A*, *B* and *C* are the length, width and thickness of a single product.

Table 2

Calculated data of root crops

Type of plants	Linear dimensions, m			*V-10*$^{-7}$, m	*F-10*$^{-4}$, m	*(V/F)*-10^{-3}, m
	A-10^{-3}, m	B-10^{-3}, m	C-10^{-3}, m			
Root vegetables	25-40	3-6	3-6	2,2-14,4	3,2-10,3	0,7-2,6

On the basis of the obtained data of the constant heating time of the root crops the heating rate values depending on the geometric characteristic and moisture content in the products were determined (Fig. 1). The analysis of the figures shows that the heating rate depends on the moisture content in the product and the size of the crushed root crops. Analysis of the figures shows that the heating rate depends on the moisture content in the product and the size of shredded root crops.

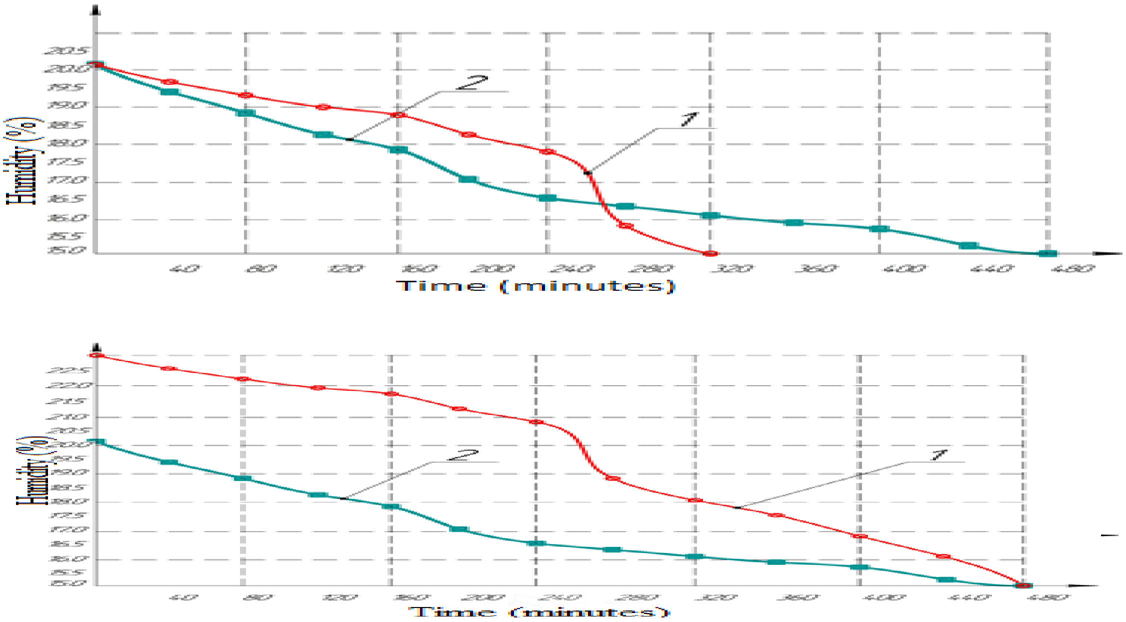

Fig. 1,2. The heating rate of root crops depending on the geometric characteristics and moisture content in the products

CONCLUSION. Using the theoretical provisions of the Fourier method, the nature of the temperature distribution is established. The proposed methods make it possible to determine the duration of the emitters and the pause period. Consequently, the quality characteristics of products with high biological activity in infrared drying can be maintained by changing the duration of the emitter operation period and the pause period.

References:

1. M.D. Sushkov. Sugar beet as the main source of sugar production in our country. *“Achievements of science and agriculture”*. **2006**. 54.
2. L.P. Rychkova. Adjustable IR heating in the drying processes of pine nuts: abstract. dis. *“Candidate of Technical Sciences”*. **1990**. 25.
3. R.S. Reshetova. Electromagnetic processing during beet storage and processing. *“News of University Food technology”*. **2011**. 123.
4. L.A. Lyagina. Improving the efficiency of drying products of plant origin due to infrared-convective effects: abstract. dis. *“Candidate of Technical Sciences”.* **2010**. 23.
5. A.S. Ginzburg. Calculation and design of drying plants of the food industry. “*Agropromizdat”.* **1985.** 335.
6. I.V. Altukhov. Reduction of energy consumption in the processes of drying vegetable raw materials. Actual problems of agro industrial complex: mat. region. *“Scientific and practical conference”*. **2005**. 15.
7. Sh. Sultanova, J. Safarov, A. Usenov, T. Raxmanova. Definitions of useful energy and temperature at the outlet of solar collectors. // E3S Web of Conferences: Rudenko International Conference. *“Methodological problems in reliability study of large energy systems”*. **2020**. 1.
8. I.V. Altukhov. Investigation of drying process of carrot roots by IR EnergoData. *“Bulletin of the ISAA”*. **2011**. 26.
9. Y.M Plaksin. Fundamentals of the theory of infrared heating. *“Monography”*. **2007**. 168.
10. S.A. Ilyina. Experimental determination of the coefficient of thermal conductivity of vegetables: Abstract. dis. *“Candidate of Technical Sciences”*. **2006**. 24.
11. Sh. Sultanova, J. Safarov, A. Usenov, T. Raxmanova. Definitions of useful energy and temperature at the outlet of solar collectors. // E3S Web of Conferences: Rudenko International Conference. *“Methodological problems in reliability study of large energy systems”*. **2020**. 1-5. https://doi.org/10.1051/e3sconf/202021601094.
12. A.J. Esquijarosa, U.H. Jáuregui, A.D. González, S.L. Martínez. Spray Drying of Aqueous Extract of Mangiferaindica L. Scale up for the Process. *“World Applied Sciences Journal”*. **2009**. 408.
13. P.V. Masevich. Intensification of the convective drying process in a flow-type apparatus. P.V. Masevich, O.S. Natareev, S.V. Natareev. Third All-Russian Student Scientific and Technical Conference. *"Intensification of heat and mass transfer processes, industrial safety and ecology".* **2012**. 97.
14. N.V. Zhuravleva and others. “*Coloring of textile materials”*. **2007**. 368.
15. L.N. Mironova. Flower science. *“High school”*. **2004**. 152.
16. S. Stefanov “*Light and light reproduction in printing”.* **2009.**