# Calculation of the drying process of dietary materials in solar dryers

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**Abstract.** The study introduces a systematic approach to mathematically and computationally model the intricate dynamics inherent in solar storage dryers. A notable contribution of this research lies in the establishment of a methodology for creating mathematical and computer models tailored specifically for solar storage dryers. By devising a structured framework for such modeling, the study endeavors to enhance the understanding of the drying process and its intricacies within the context of herbaceous dietary materials. Through this innovative approach, researchers seek to bridge the gap between theoretical insights and practical applications in the field of solar drying. The developed technique holds the potential to not only deepen our comprehension of drying processes but also pave the way for optimized drying strategies in the context of herbaceous dietary materials. This pioneering effort underscores the role of scientific inquiry in advancing sustainable and efficient practices within the realm of food processing and preservation.Empirical values of drying rate constants and their changes with time are shown. Empirical coefficients $K_{u1}$= 5.3956 1/day; $k_{u2}$= 0.0148 1/day; $k_{w1}$=0.9858; $K_{w2}$=-7.2359. Correlation coefficient matrices, showing the relationship between the drying rate constant and the main environmental factors, indicate that the relationship between the drying rate constant and temperature is non-linear. Approximation of the kinetic curves based on the dynamic mass transfer equation and the proposed empirical dependences of the drying rate constants on temperature has been carried out.

## 1. Introduction

In the world, providing the population with quality food is considered one of the important tasks [1]. Particular attention is paid to the improvement of energy-saving equipment and technologies for processing food dietary herbs while preserving their biologically active components [2].

The problems of energy supply to the population of the Earth have not been fully resolved to date. About 1 billion people worldwide, or 13% of the world's population, still do not have access to electricity [3] and 2.4 billion people still traditionally use biomass for cooking [4]. According to the International Monetary Fund, the annual growth of world energy consumption is about 1.7% [5].

Considering such rates of energy consumption, it can be assumed that in the coming decades, hydrocarbon raw materials will no longer be able to meet the basic needs of the world economy in electricity. In industries, solar installations are used, the problems of which are to reduce the processing time of raw materials, reduce the cost of electricity and labor, improve the quality of the final product, and improve the technological processes of drying [6, 7].

The influx of solar energy reaching Earth surpasses the cumulative energy held within the planet's oil, gas, coal, and other energy reserves, encompassing renewable sources as well. A mere fraction, specifically 0.0125%, of solar energy has the potential to fulfill the present global energy demands, while a utilization rate of 0.5% could comprehensively address future energy requirements. The scale of solar energy's capability is so vast that prevailing assessments indicate the solar energy reaching Earth each minute could satisfy the entire annual global energy consumption of humanity [8].

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products by means of infrared rays, improvement of drying methods (convective, conductive, infrared, microwave) and development of methods for the movement of the drying agent [9-11].

At the same time, scientific research is being carried out in the world in priority areas for the development of drying technology and equipment; efficient use of alternative energy; preservation of the constituent bioactive substances of the product; drying products by means of infrared rays; improvement of drying methods (convective, conductive, infrared, microwave); development of methods for the movement of the drying agent. However, insufficient research is being conducted on the drying of dietary and food herbs, in terms of intensifying the technological process, and also on preserving the dietary properties of the raw materials in the finished product to a high degree.

## 2. Materials and methods

Employing a systems thinking approach, a methodology has been devised to mathematically and computationally simulate solar storage drying plant operations. This technique incorporates mathematical models tailored to each quasi-apparatus, notably encompassing a computer-generated model for tracking material temperature alterations, variations in thermal energy exchange, shifts in equilibrium between solid and gaseous phases, and fluctuations in the mass of evaporating water due to mass transfer. A validation process involving computer and physical experiments led to the refinement of the model, ensuring its compatibility with real-world conditions, particularly in terms of mass transfer and heat transfer coefficients [5].

The results of experiments on drying in a highly efficient energy-saving solar storage dryer are presented in Table 1.

**Table 1.** Results of experiments on drying in an energy-saving solar storage dryer.

| Time, ***t*** | $8^{00}$ | $11^{00}$ | $13^{00}$ | $15^{00}$ | $17^{00}$ | $19^{00}$ | $21^{00}$ | $22^{00}$ |
|---|---|---|---|---|---|---|---|---|
| Air temperature, $T_a$ | 23ºC | 31ºC | 36ºC | 37ºC | 34ºC | 28ºC | 25ºC | 20ºC |
| Installation temperature, $T_v$ | 35ºC | 47ºC | 58ºC | 60ºC | 52ºC | 37ºC | 31ºC | 28ºC |
| Paraffin temperature, $T_p$ | 26ºC | 37ºC | 45ºC | 57ºC | 56ºC | 44ºC | 38ºC | 31ºC |
| Material weight, ***P,g*** | 2000.0 | 1910.0 | 1435.2 | 966.5 | 634.6 | 390.2 | 310.2 | 252.3 |

## 3 Results and discussion

Processing gives the results shown in Fig. 1-3. The matrix of correlation coefficients is shown in Table 2. Empirical coefficients: $K_{u1}$=5.3956 1/day; $k_{u2}$=0.01481/day; $k_{w1}$=0.9858; $K_{w2}$=-7.2359 (Figures 1, 2, and 3).

**Table 2.** Correlation matrix of coefficients of the relationship between the drying rate constant and process parameters.

| | $k_{ss}$ | $T_a$ | $T_v$ | $T_p$ | $t$ | $w_{so}$ |
|---|---|---|---|---|---|---|
| $k_{ss}$ | 1.0000 | 0.0886 | 0.1592 | 0.5660 | 0.7029 | -0.7496 |
| $T_a$ | 0.0886 | 1.0000 | 0.9769 | 0.6920 | -0.4747 | 0.3519 |
| $T_v$ | 0.1592 | 0.9769 | 1.0000 | 0.7815 | -0.3386 | 0.2095 |
| $T_p$ | 0.5660 | 0.6920 | 0.7815 | 1.0000 | 0.2261 | -0.3838 |
| $T$ | 0.7029 | -0.4747 | -0.3386 | 0.2261 | 1.0000 | -0.9794 |
| $w_{so}$ | -0.7496 | 0.3519 | 0.2095 | -0.3838 | -0.9794 | 1.0000 |

Comparison of the outcomes derived from representing the constant as a function of temperature within the apparatus and the surrounding environment highlights a remarkable similarity in accuracy between the two approaches. This convergence in accuracy paves the way for the calculation of operational modes within the installation, guided by external parameters of the energy source. These parameters encompass factors such as ambient temperature, relative humidity, as well as the conditions and duration of insolation.

By harnessing the predictive power of these models, it becomes feasible to tailor the operation of the installation in accordance with the ever-changing dynamics of the external environment. The utilization of external parameters, like temperature, humidity, and sunlight conditions, allows for a more adaptive and responsive system that optimally adjusts its processes to achieve the desired outcomes. Such an approach is particularly relevant in harnessing solar energy, where the variability of weather and sunlight patterns necessitates a flexible and adaptive system.

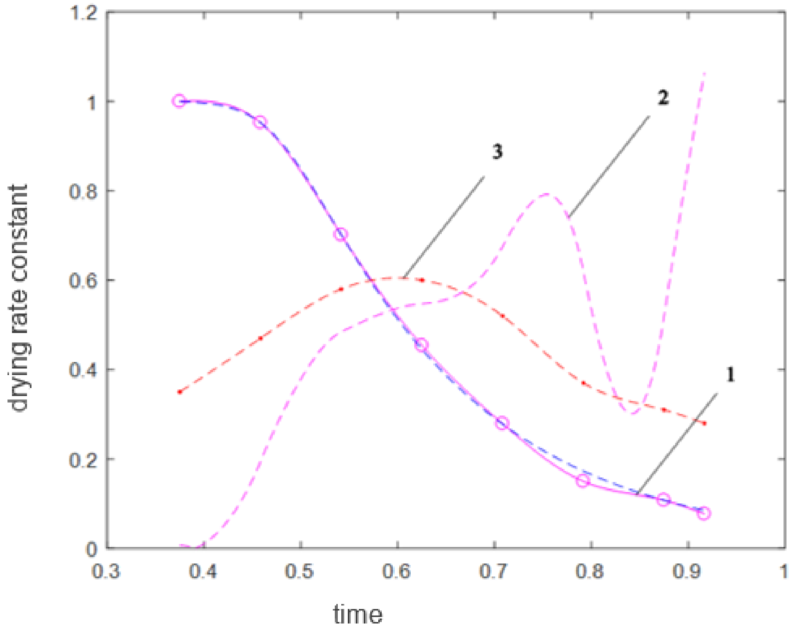

**Fig. 1.** Drying curves of dietary grass in an energy saving solar storage dryer: 1-drying curve; 2-empirical drying rate constant values $k_{ss}*10^{-1}$per day $^{-1}$; 3-temperature in the installation $T_a*10^{-2}$ °C.

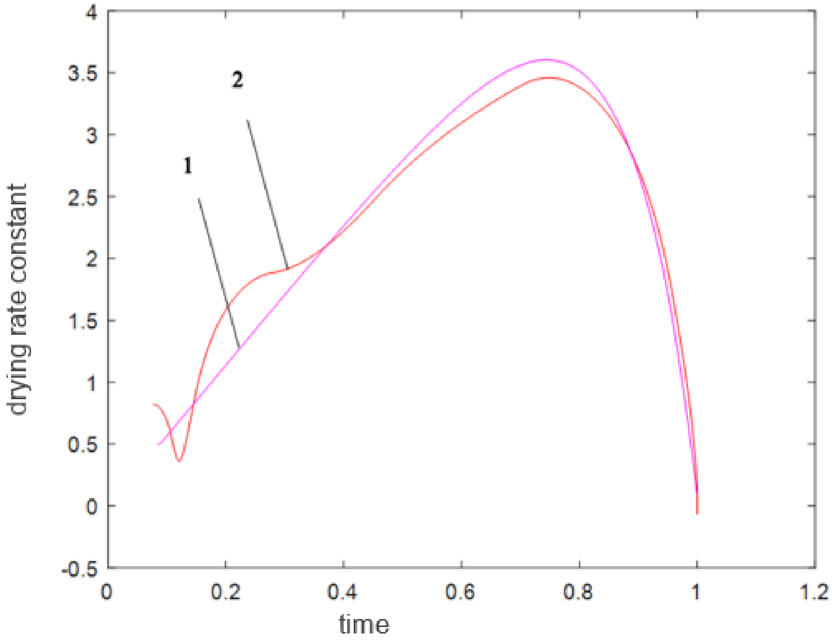

**Fig. 2.** Drying speed curve: 1-calculated; 2-empirical.

The ability to factor in these external parameters in the modeling and operation of the installation represents a significant stride towards sustainability and efficiency. It enhances the ability to capture available solar energy and channel it effectively into the drying processes, thereby contributing to resource optimization and minimizing energy waste. Furthermore, this approach aligns well with the overarching goals of green technologies and environmentally-conscious practices, where harnessing renewable energy sources and optimizing their utilization are central tenets.

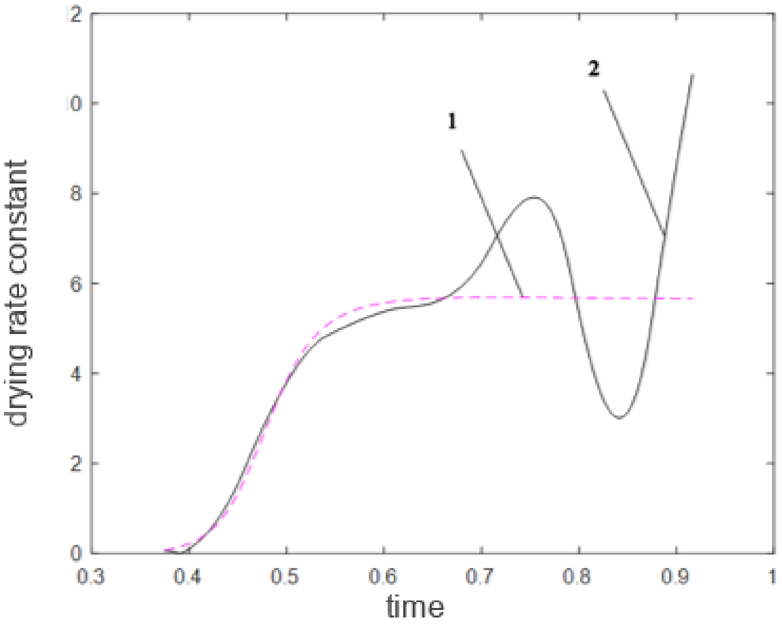

**Fig. 3.** Calculated (1) and empirical (2) values of drying rate constants.

The accuracy parity observed in representing the rate constant as a function of temperature inside the apparatus and in the environment is a crucial advancement that empowers the calculation of installation modes based on external energy source parameters. This holistic approach, considering external factors like temperature, humidity, and solar insolation, not only enhances operational efficiency but also aligns with sustainable practices, offering a promising pathway towards energy optimization and responsible resource management.

## 3. Conclusions

The correlation coefficient matrices, which illustrate the connections between the drying rate constant and key environmental factors, reveal that the association between the drying rate constant and temperature is nonlinear in nature.

The kinetic curves were approximated using the dynamic mass transfer equation, along with the introduced empirical relationships governing the drying rate constants with respect to temperature. Additionally, the desorption isotherm equation was formulated using the Posnov equation, complemented by a linear correlation between the equilibrium parameter and temperature. The study concludes that a comprehensive formula can be developed to account for the temperature-dependent rate constant under varying shading and insolation conditions. In cases of insolation, computations are conducted utilizing the concept of the "effective temperature in the sun."

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