OPTIMIZATION OF GRAIN DRYING PROCESSES UNDER REDUCE ENERGY CONSUMPTION

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Abstract: Drying of heterogeneous systems, one of which also includes sorize groats, is a complex process that has not yet been fully explored because of the essential problems that arise in research of various parameters influencing the drying process. Close down methods of calculating the drying kinetics are the most progressive, based on the study of general principles of the process, which approaches the drying theory and practice. Best dependency generalized equation drying process is dependent multiplicative parameter output factors influencing this process. For experimental data was compiled program that brings preventive multiplicative equation to linear form. Data processing package was used to approximate mathematical MathCAD program dependencies discrete experimental data with continuous functions. Problem identification process we made as a drying curves graphically built on mathematical equations.
Keywords: cereals, optimization, mathematical modeling, temperature of the drying agent.

Introduction

Corn is the most important staple food for humans. According to the FAO (Food and Agriculture Organization of the United Nations) annually lose over 20% of the grain harvested worldwide. Most insect activity and development is due to fungi and molds [4,6], therefore an effective method of preserving grain is hydrothermal processing, the elimination of most of the water and getting food-product concentrates instant power is in harmony. Detailed analysis of existing dryers in operation, show that their operation can be made more efficient by providing them with monitoring and control systems, computer-driven, based on calculating the programs of one or more parameters, depending on the input data changes . Designing an automatic temperature control system in a drying plant requires knowledge of complex parameters, whose interdependence is expressed by correlations of various shapes.

1. Theoretical aspects of mathematical modeling of drying processes

Experimental research conducted to study any process, including its evolution over time can not be in as great numbers. For this reason, in all areas, the theoretical study of a certain process is established mathematical model, applying principles and laws known algorithm that describes the evolution in time or after certain mutual dependencies when there are external factors known or appreciated by the specialist. For these reasons, frequently setting possibly looming theoretical mathematical model [3, 4, 6], and then finalized based on experimental data.

Usually, experimental data are presented in the form of paintings, which consist of pairs of data (Ui, τi) if one independent variable dependencies or data sets consist of (Ui, τi, ti, ...) dependencies for several independent variables. Here, U - moisture content,% τ - drying time, min., T - temperature, ° C, N - nominal power of the magnetron, i = 1, 2, .., n_{-1}, n - number of measurements.

The problem is dependency discrete approximation U_i (τ_i) and U_i (τ_i, t_i) with continuous dependence U (τ) and U (τ, t, N).

There are three main types of approximations: interpolation and extrapolation (prediction) data, regression data, filtering data with subsequent interpolation or regression. Interpolation function U (τ) passes through the points (U_i, τ_i) and approximate dependence U_i ($_{\tau i}$) only within the range that contains the values τ_i. On extrapolation, this dependence is approximated outside this range. On regression function U (τ) does not pass through the points (U_i, τ_i). Regression technique is called smoothing experimental data. Data filtering, data (which is considered wrong or useless) or excluded from the initial set, or reduce their influence according to some filtering algorithm.

This restriction is due to the high degree of the polynomial obtained by the essential increase of numerical errors.

The idea of the method is to determine the coefficients chosen class of functions (eg polynomial) [3, 7]:

$$U(\tau) = a_o + a_1\tau + a_2\tau^2 + \ldots + a_{N-1}\tau^{N-1} \tag{1}$$

Provided coincidence function values of U with values in nodes τ_i U_i function interpolation. In the experiments performed measurement accuracy is not high (1-2 digits after comma) and the number of measurements in an experiment is large (N = 15 - 20). Filtering techniques are applied to analyze the signs to exclude the effects of noise, ie intensive functions oscillators.

Thus, our experience is preferable to regression of experimental data. If measurements indicate a random character before performing experimental data approximation is required statistical processing of data according to the methodology specified in, and in the case of deterministic data can be directly applied the methods given in [5].

Regression is to determine such a function U (τ), which in some sense minimizes deviations | U_i (τ_i) - U_i (τ_i) |. The success of such approximations depends largely on the correct choice of classes of functions caution.

Classes of functions used in mathematical modeling of drying process were hydrothermally processed sorize the polinominale

$$U(\tau, A, B, C, \ldots) = A + B\tau + C\tau^2 + D\tau^3 + \ldots \tag{2}$$

2. Dependencies discrete approximation of the experimental data with continuous functions

Analysis of experimental data obtained and the literature on drying technologies [1, 2, 5] shows that the dependence of moisture during drying is a monotonic function sufficiently smooth with strictly positive values. This allows us to assume that the class can be chosen polynomial functions and polynomial degree will be small (3 or 4). The purpose is the calculation of regression parameters A, B, C, ... ε_i is determined from the condition that the average sum squared deviation is minimized. So it minimizes the functional dependence:

$$\phi(\tau, A, B, C) = \frac{\sum_{i=1}^{N} (U_i - U(\tau_i))^2}{N} \rightarrow \min \tag{3}$$

Thus the problem reduces to determining the minimum value of the function of several variables.

According to choice or a polynomial of order m (m <N):

$$U_m(\tau) = a_0 + a_1\tau + a_2\tau^2 + \ldots + a_m\tau^m \tag{4}$$

Function will be:

$$\phi = \sum_{i=1}^{n}\left(U_i - U_m(\tau_i)\right)^2 \to \min \tag{5}$$

Functional is minimum if:

$$\frac{\partial\phi}{\partial a_i} = 0, \qquad i = 0, m \tag{6}$$

Get m +1 equations:

$$\sum_{i=0}^{n}\left(U_i - a_0 - a_1\tau_i - a_2\tau_i^2 - \ldots - a_m\tau_i^m\right)\cdot\tau_i^k \tag{6}$$

Or:

$$a_0\sum_{i=0}^{n}\tau_i^k + a_1\sum_{i=0}^{n}\tau_i^{k+1} + a_2\sum_{i=0}^{n}\tau_i^{k+2} + \ldots + a_m\sum_{i=0}^{n}\tau_i^{k+m} = \sum_{i=0}^{n}U_i\tau_i^k \tag{7}$$

note:

$$b_k = \sum_{i=0}^{n}\tau_i^k \qquad\qquad c_k = \sum_{i=0}^{n}U_i\tau_i^k \tag{8}$$

and present explicit system:

$$\begin{cases} b_0a_0 + b_1a_1 + b_2a_2 + \ldots + b_ma_m = c_0 \\ b_1a_0 + b_2a_1 + b_3a_2 + \ldots + b_{m+1}a_m = c_1 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_ma_0 + b_{m+1}a_1 + b_{m+2}a_2 + \ldots + b_{2m}a_m = c_m \end{cases} \tag{9}$$

We have obtained a system of m +1 inhomogeneous algebraic equations with respect to coefficients a_0 .... a_m. It can be shown that the determination of this system:

$$D = \begin{vmatrix} b_0 & b_1 & b_2 & \cdots & b_m \\ b_1 & b_2 & b_3 & \cdots & b_{m+1} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ b_m & b_{m+1} & b_{m+2} & \cdots & b_{2m} \end{vmatrix} \tag{10}$$

called Gramm's determinant is not zero [158]. So the system of equations has only one solution and that is achieved by the function U (τ) which gives the functional minimum.

To determine how far the curve U (τ) the experimental data can be used several rules:

1. Maximum absolute deviation $E_\infty(U) = \max\{U(\tau_i) - U_i\}$
2. Standard deviation $E_m(U) = \frac{1}{N}\sum_{i=1}^{N}\left|U(\tau_i) - U_i\right|$
3. Standard deviation practical $E_p(U) = \frac{1}{N}\sum_{i=1}^{N}\left|U(\tau_i) - U_i\right|^2$

It is useful to know all these deviations, to make conclusions about the function obtained.

Based on this algorithm are developed computer programs in *MathCAD* programming environment.

3. Mathematical models of drying on the application of combined convection and SHF energy from the magnetron power level of 25% of nominal N –

Further identification will illustrate parametric linear equations by establishing mathematical models of drying grain cooked sorize. It should be noted that because mathematical descriptions are obtained based on experimental data, a direct result of identification is a difference equation, so in discrete, then the adopting spectral analysis results are obtained in the continuous mathematical descriptions, ie polynomial equations.

Pentru un sistem neliniar, la care mărimea de ieşire y(t) şi mărimea de intrare u(t) se cunosc, constituind serii dinamice experimentale discrete, modelul parametric liniar are forma generală:

$$\tau(t,U) = C_9 + C_{10}\cdot t + C_{11}\cdot t^2 + C_{12}\cdot t^3 + C_4\cdot U^3 + C_5\cdot U^2 + \\ + C_6\cdot U + C_7\cdot t\cdot U + C_8\cdot t^2\cdot U + C_3\cdot t\cdot U^2 \qquad (11)$$

C =

	0
0	3.0000000
1	3.0000000
2	3.0000000
3	$-4.7784570\cdot10^{-5}$
4	$-2.4625200\cdot10^{-5}$
5	0.0142874
6	-2.4614985
7	0.0155124
8	$-2.2871461\cdot10^{-5}$
9	155.4450586
10	-1.4813114
11	$4.9738216\cdot10^{-3}$
12	$-6.4573975\cdot10^{-6}$

Analytical expression of drying time depending on humidity and temperature is given by the following equation::

$$\tau(t,U) = 155.4450586 - 1.4813114\cdot t + 0.0049738\cdot t^2 - 0.0000065\cdot t^3 - 0.0000246\cdot U^3 - \\ - 0.0142874\cdot U^2 - 2.4614985\cdot U + 0.0155124\cdot t\cdot U - 0.0000229\cdot t^2\cdot U - 0.0000478\cdot t\cdot U^2 \qquad (12)$$

An illustration of equation 11 is presented in Figure 1 dimensional chart.

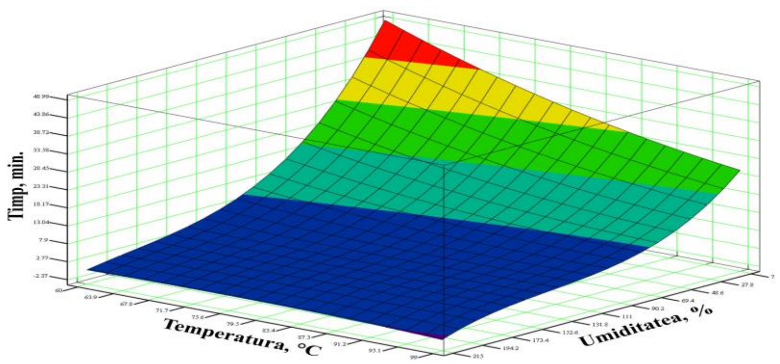

Fig.1. Correlation between drying time, water temperature and humidity in the drying product sorize energy application combined with convection + SHF 25% N at the magnetron power.

Generalized mathematical model for moisture content, ie all heating temperatures at the level of 25% of rated magnetron is shown in the equations below. Based equations were established transfer functions for the power used for all temperatures applied:

- t=60°C

$$U1(\tau) = 222.00207 - 17.053648 \cdot \tau + 0.713729 \cdot \tau^2 - 0.015097 \cdot \tau^3 + 0.000119 \cdot \tau^4 \quad (13)$$

- t=70°C

$$U2(\tau) = 222.59406 - 18.55026 \cdot \tau + 0.77787 \cdot \tau^2 - 0.01709 \cdot \tau^3 + 0.00015 \cdot \tau^4 \quad (14)$$

- t=80°C

$$U3(\tau) = 223.46572 - 20.74099 \cdot \tau + 0.95966 \cdot \tau^2 - 0.02359 \cdot \tau^3 + 0.00023 \cdot \tau^4 \quad (15)$$

- t=90°C

$$U4(\tau) = 222.85230 - 25.08453 \cdot \tau + 1.54767 \cdot \tau^2 - 0.05398 \cdot \tau^3 + 0.00075 \cdot \tau^4 \quad (16)$$

- t=100°C

$$U5(\tau) = 222.66145 - 27.63615 \cdot \tau + 1.99082 \cdot \tau^2 - 0.08265 \cdot \tau^3 + 0.00134 \cdot \tau^4 \quad (17)$$

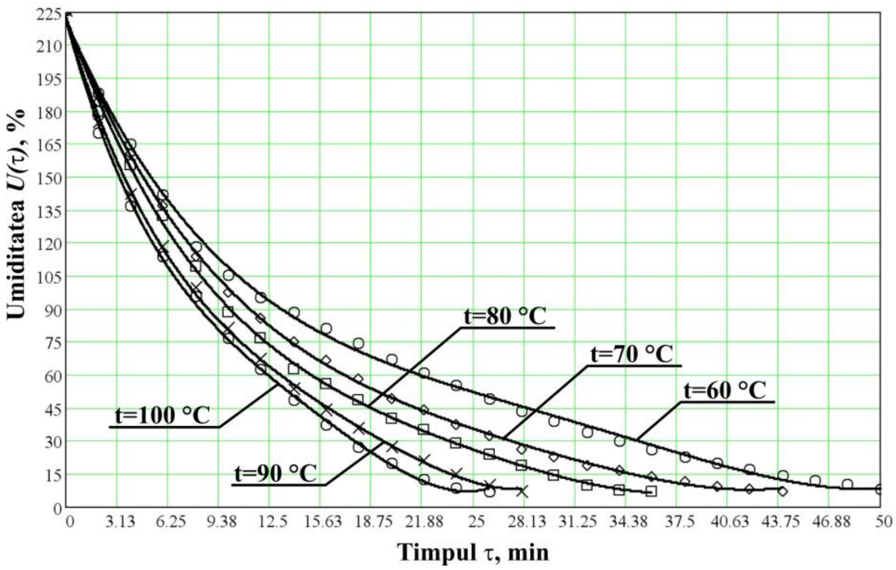

Fig. 2. Drying curves linked by mathematical formulas.

Main problebm any dynamic process is the establishment of a mathematical model based on experimental data. Problem identification process we made as a drying curves graphically built on mathematical equations. Validation model is estimated by analyzing the resulting graph, where we find that the error Experimental is within acceptable limits.

Conclusions:

Statistical software package chosen, MathCAD, allowed mathematical modeling of drying process of sorize groats, resulting mathematical regression equations. The analysis results there is a significant influence on moisture has temperature - time and temperature - temperature. The mathematical model is very good, close to the experimental data, 98% are found in the mathematical model. The mathematical model allows tracing the influence of each factor on drying control, resulting in a final grain moisture variation diagrams depending on the temperature and duration of the drying agent. Dependencies drying time depending on temperature and humidity desiccant product (Fig. 2), indicating the presence of a local optimum for this dependence.

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