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SOLAR WATER HEATING CONVECTIVE DRYER FOR DRYING MEDICAL HERBS

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ABSTRACT--*The article describes the profiles of the temperature field of the process and operating parameters of the drying of medicinal herbs. The paper substantiates the criteria for ensuring rational material temperatures by pallets and tilt angles of the approximating straight line at fixed values of the average temperature of the processed raw materials. Mathematical modeling of the drying process with a two-phase representation of the flow pattern for direct-flow and counter-current interaction of liquid and air flows without taking into account and taking into account heat consumption for evaporation has been performed. To determine the numerical values of the parameters of the mathematical model from the experimental data obtained on Matlab, a program has been developed to evaluate the minimization of the norm of the difference of vectors corresponding to the experimental and calculated temperature profiles.*

Key words-- *solar-water heating convective drying equipment, heat flow, drying medical herbs, temperature floor.*

I. INTRODUCTION

Drying (dewatering) is one of the basic methods of the best and most commonly used preservation methods. It consists of the removal of moisture from a product resulting from the simultaneous heat transfer process due to the use of heat. The drying process may affect (in part or in whole) the quality of the products from the point of view of sensory, nutritional and functional characteristics. For the successful operation of drying, there arises the necessity of choosing the appropriate method, especially for valuable products, as well as medicinal plants.

In the world of pharmaceutical development, much attention is paid, especially to the study of the preparation and processing of medicinal herbs. In this regard, applying usovershenstvennye sovremennye tehnologii protsessov and apparatov for pererabotki lekarstvennyh rasteny were razrabotany ustroystva for polucheniya kachestvennogo farmatsevticheskogo raw biologicheski Active substances vnedrena energosberegayuschaya sushilnaya tehnika and tehnologii in promyshlennost drying feedstock usovershenstvovana sushilnaya ustanovka drying lekarstvennyh rasteny, razrabotannaya on the basis of scientific justification. At the same time, it has important

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scientific and practical significance for the creation of a rational design of a drying unit, which works without electricity with the use of innovative methods for the storage of medicines.

The use of new heating methods to develop a drying system attracted the attention of a significant number of researchers in recent years. Several researchers have shown the integration or combination of these technologies with conventional drying methods. We studied combined microwave drying, hot air drying, combined dryers, vacuum drying, etc.

In the work of A.B.Sukhotsky et al. [1], an experimental study of the process of heat transfer of a single-beam bundle from finned tubes when heat was supplied by a mixed convection of hot air was considered. The author obtained the experimental dependences of the heat transfer of finned single-row beams in the limiting selected ranges of the Grashof and Reynolds numbers. It is shown that the heat transfer with such a mixed convection is 2.5–3 times higher, with relatively free convection, and the heat transfer growth rate with an increase in the Reynolds number is greater than with forced convection. Other forms of the presentation of these results of the experiments were analyzed and determined, that the number of Nusselt has a uniform power dependence on the number of Reynolds for any other height of the exhaust batch. It was established that the linear dependence of the number of Reynolds from a square root from the number of Grafsof, as well as the proportionality coefficients for different heights were determined.

S.V. Karpov et al. [2] showed the process of convective heat transfer in cyclical recirculating heating devices. They performed an analysis of the dependences of average and local coefficients in the process of heat transfer from operating and geometrical parameters; generalized equations are proposed that are similar for their calculation. It is shown that in the case of loading during operation of the cyclone chamber, a few of the several procurements use the size of the external recirculation due to the differences in temperature.

The following work [3] presents experimental studies of convective drying, heat transfer in thin wet materials. The authors presented the results of the study of heat transfer during convection during the drying of thin and flat moist capillary-porous materials. The experimental equations of the authors' works are presented for determining the densities of heat fluxes, the average integral temperatures, the drying time, and the evaporation rate of moisture during the second drying period. The relation between the densities of the heat flows in the first and second periods with a change in temperature during the second period of the process is established. A connection was found to determine the temperature during the incident drying rate taking into account the heat on the heating of wet material. Displays are shown for determining the temperature during the second period with respect to the temperature coefficient of drying, the rate of heating of the wet material and the rate of heating of the wet material. As a result of the studies, the basic kinetic characteristics necessary for calculating the heat and moisture in the drying process were determined.

II. RESAULTS

In [4], the latest achievements of the new thermal combined drying by hot air of agricultural crops are shown. The development of an effective drying system with a combined new thermal and conventional hot drying agricultural crops has potentially become an alternative to the traditional drying method. Thanks to the synergistic effect, total energy and time can be significantly reduced, and the final quality of agricultural crops can be saved.

The growing interest and research in recent years has shown that a new thermal technology with dry, hot air can be used adequately when drying agricultural crops.

Models of evaporation of water droplets taking into account convection, convertibility, and heat radiation take into account the main interconnected heat exchange processes, including phase transitions. Typical speed and temperature profiles were found in a high-temperature gas-drop system with an external gas-gas temperature from 100 to 800 ^{0}C. Different wordings of the problems are considered, which are significantly different by the type of processes and factors under consideration [5].

Критический тепловой поток в процессе кипения и его зависимость от характеристик теплоотдающей стенки экспериментально установлены, так, теплообмен и критический тепловой поток сильно зависят как от физических свойств хладагента, так и от ряда характеристик теплоотдающей стенки [6].

A number of leading scientists carried out a two-dimensional analysis of transport phenomena occurring during convective drying: apple slices [7], the corresponding effective diffusions for various food materials [8] were determined, the temperature was limited to: product specifica konvektivnoy mikrovolnovoy and drying leaves ukropa (anethum graveolens L.) [10] mehanizmy teploperedachi at konduktivnoy gidrosushke kusochkov pumpkin (cucurbita maxima) [11] issledovany identifikatsii medical rasteny with pomoschyu multispektralnogo analiza [12] razrabotana geliosush The installation on the basis of theoretical studies of the accumulation of thermal energy [13-14], simulated the motion of a separate convective dryer in a plastic solar dryer [15]. Implementation of the directions aimed at improving the productivity of the production of processed products from plant raw materials on the basis of modern technological processes and food processing equipment was carried out.

Analysis of theoretical and experimental studies. Based on the results of research, the selection of the type and design of the drying unit and the arrangement of materials and heat flows is carried out on the basis of the following requirements:

1. Providing the required end values of temperature and humidity of the material, as well as the outgoing air flow.

2. Ensuring the quality of the drying process, depending on the dispersion, moisture and temperature.

3. Restrictions on different types of physico-chemical, organoleptic changes in the final products.

In accordance with the requirements specified above, the required levels of settings for the operational parameters and the conditions of contact of the phases are provided.

The systemic decompression of the task of analyzing and synthesizing a complex, interconnected complex of heat-exchanging, aero- and hydrodynamic, mechanical and other phenomena requires an initial stage of research.

For the purpose indicated above, we proceed to simulate the influence of heat flows on the horizontal temperature profile and phase in the proposed heated drying unit with a fixed floor.

We analyze the features of the interaction of air blown through the drying chamber with hot water flowing through the supply coils. The heat flow diagram is shown in Fig. 1.

Estimates were obtained by the method of least squares using the built-in minimizer functions of Matlab.

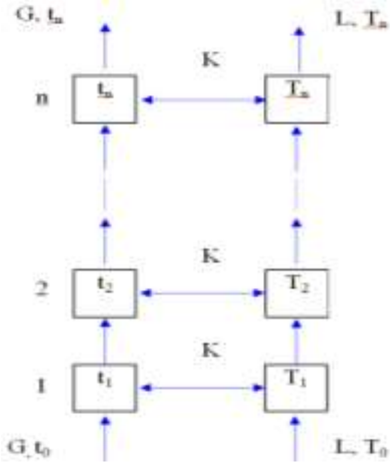

Figure 1: Direct-flow two-phase scheme of heat flows in the apparatus

by heat carrier phase:

$$\begin{cases} LT_0 - LT_1 - K_1(T_1 - t_1) = 0 - for\ 1st\ pallet \\ LT_1 - LT_2 - K(T_2 - t_2) = 0 - for\ 2st\ pallet \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ LT_n - LT_n - K(T_n - t_n) = 0 - for\ n\ pallet \end{cases} \quad (1)$$

steam phase:

$$Gt_0 - Gt_1 + K(T_1 - t_1) = 0 \text{ – for 1st pallet}$$

$$Gt_0 - Gt_2 + K(T_2 - t_2) = 0 \text{ – for 2st pallet} \quad (2)$$

$$Gt_0 - Gt_n + K(T_n - t_n) = 0 \text{ – for n pallet,}$$

Here: T_1 - temperature at the upper surface of the corresponding coil pipe (we take equal average water temperature); t_i - air temperature in the corresponding rows; T_0–inlet temperature of water into the pipe; t_0 – setting air temperature; L is the amount of water dissipation for heat capacity (a certain analogue of the entropy flow); G – respectively for air; K – the ratio of the heat exchange flow to the difference in temperature of the phases.

To go to dimensionless variables, we introduce the ratios of the ratios of the intensities of the entropy fluxes to L:

$$k = \frac{K}{L}, \quad g = \frac{G}{L}.$$

Then, for the first authorization, you can express it as follows:

$$\begin{cases} T_1 = \frac{T_0 + kt_1}{1+k} \\ t_1 = \frac{gt_0 + kT_1}{g+k} \end{cases} \quad (3)$$

Such a presentation is convenient for solving the occurrences of a heat balance in relation to unknown values of temperatures by the iteration method. It is especially convenient when considering flow-through and complex flow arrangements and, in the future, taking into account non-linearities.

The calculation is made sequentially from bottom to top. Calculations show that there are enough 10-fold measurements to achieve the required accuracy.

Before you start researching the accuracy of the model's identification, you need to get the quasistonal estimates of g and k for the test material without taking into account the flow of evaporating moisture - it's not necessary.

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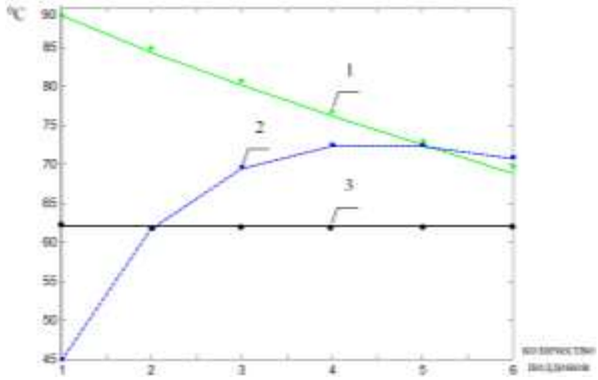
The comparison of the approximations of the calculated and experimental profiles presented in Fig. 2 indicates that the assumption of the equality of the temperatures of the gaseous phase and the material does not make it possible to obtain the required level of adequacy.



1 – calculated coolant temperature; 2 – gas phase temperature; 3 – material temperature

Figure 2: Calculated and experimental temperature profiles with regard to the flow for evaporation

At this stage, a concurrent flowchart for arranging heat and air flow is also checked (Fig. 3).

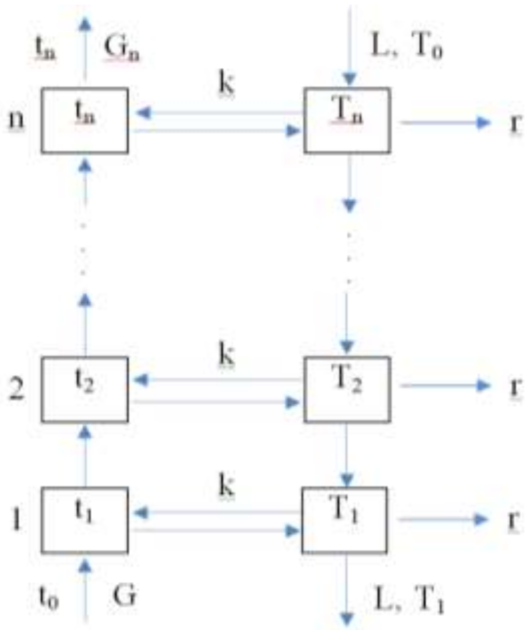


Figure 3: Organization of the flow flow heat flow diagram

Balance equation for the first pallet:

by liquid phase

$$LT_2\text{-}LT_1\text{-}K(T_1\text{-}t_1)\text{-}r=0, \tag{4}$$

under the gaseous phase

$$Gt_0\text{-}Gt_1+K(T_1\text{-}t_1)=0, \tag{5}$$

in an iterative form

$$T_1 = \frac{T_2 - r + kt_1}{1+k}, \tag{6}$$

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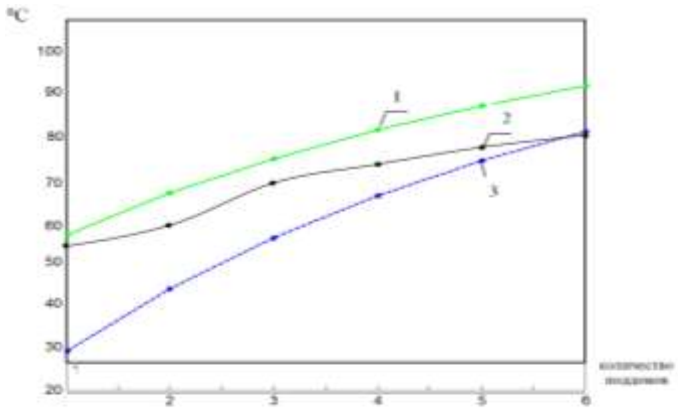
$$t_1 = \frac{g t_0 + k T_1}{g + k} \tag{7}$$

Procedures on Matlab:

```
function Tt=sushilkaobr(parametri)
k=(parametri(1));
g=(parametri(2));
T0=parametri(3);
t0=parametri(4);
n=parametri(5);
r=(parametri(6));
T(1:n)=50;t(1:n)=50;
Tp=100;
while norm(t-Tp)>.001
  Tp=t;
  t(1)=(g*t0+k*T(1)-r)/(g+k);
for j=2:n
t(j)=(g*t(j-1)+k*T(j)-r)/(g+k);
end

T(n)=(T0+k*t(n)-0)/(1+k);
for j=n-1:(-1):1
   T(j)=(T(j+1)+k*t(j)-0)/(1+k);
End
```



1 – average temperature in coils under pallets; 2 – air temperature in contact with the pallet; 3 – material temperature

Figure 4: Profiles of calculated and experimental values of temperatures under the scheme of countercurrent flow organization

Fig. 4 shows profiles of a flow-through flow management system. The results strongly suggest unacceptable drying unevenness on the basis.

The implementation of the identification procedure has shown that the model parameter estimates are in the range *k* of about ~0.36, g is around ~0.56, and r takes the minimum value. It should be noted that the decision of

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the problem of identification to a large extent depends on the initial approximations of the model parameters. For verification of the results, the solution of the system of linear equations by the method of the inverse matrix was also obtained.

The coefficient matrix of the equation system (8–9) is a four-diagonal matrix:

$A_{ii}=-1-k$ $\quad$ $i=1,3\ldots 2n-1$

$A_{ii}=-g-k$ $\quad$ $i=2,4\ldots 2n$

$A_{ii+1}=k$ $\quad$ $i=1,3\ldots 2n-1$

$A_{i+1,i}=k$ $\quad$ $i=1,4\ldots 2n$

$A_{ii+2}=1$ $\quad$ $i=1,3\ldots 2n-3$

$A_{i+3,\ i+1i}=g$ $\quad$ $i=1,3\ldots 2n-3$

Table 1: The matrix of coefficients looks as follows:

T_1	t_1	T_2	t_2	T_3	t_3	. . .	T_n	t_n	
-1-k	k	1							r
k	-g-k								$-gt_0$
		-1-k	k	1					r
	g	k	-g-k						0
				-1-k					x

The calculation time by the inverse matrix method is approximately two times shorter than the calculation time by the iterative method.

In addition, as in previous cases, we use separate accounting of water, material and air temperatures. The corresponding flow arrangement diagram is shown in fig. 5.

Equations of a stationary mode for a 3-phase model:

for 1st pallet

$$\begin{cases} LT_{n0} - LT_{n1} - K_{nm}(T_{n1} - T_{m1}) + K_{ng}(T_{n1} - T_{g1}) = 0 \\ K_{nm}(T_{n1} - T_{m1}) - K_{mg}(T_{m1} - T_{g1}) = 0 \\ GT_{g0} - GT_{g1} - (T_{n1} - T_{g1}) + (T_{m1} - T_{g1}) = 0 \end{cases} \tag{8}$$

We introduce the following notation:

$$\frac{K_{nm}}{L} = k_{ng}; \quad \frac{K_{ng}}{L} = k_{ng}; \quad \frac{K_{mg}}{L} = k_{mg}; \quad \frac{R}{L} = r \tag{9}$$

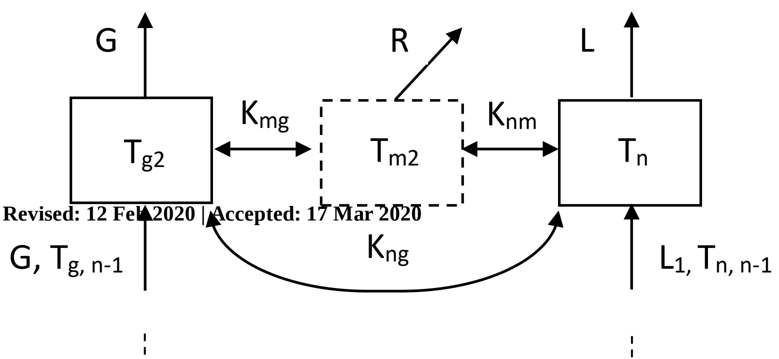

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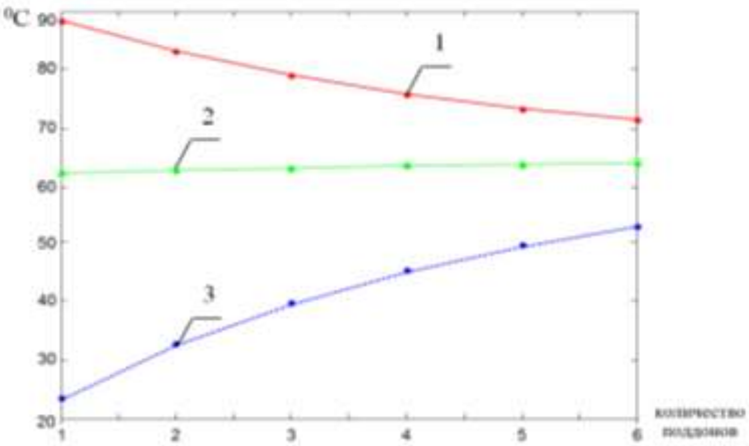
Figure 5: Three-phase model of the movement of heat flows

Let us consider the considered relations to the iterative form:

$$\begin{cases} T_{n1} = \frac{T_{n0}+k_{nm}T_{m1}+k_{ng}T_{g1}}{1+k_{nm}+k_{ng}} \\ T_{m1} = \frac{k_{nm}T_{n1}+k_{mg}T_{g1}-r}{k_{nm}+k_{mg}} \\ T_{g1} = \frac{gT_{g0}+k_{ng}T_{n1}+k_{mg}T_{m1}}{g+k_{ng}+k_{mg}} \end{cases} \quad (10)$$

Figure 6. three-phase model identification results are presented.



1 – average temperature in the pipeline of the pallet; 2 – average temperature of the material; 3 – the average temperature of the gas phase

Figure 6: Identification of the three-phase model

Model parameter estimates received (under conditions T_{n0}=95 ^{0}C; T_{g0}=12 ^{0}C): g=0,5752; k_{nm}=0,0261; k_{mg}=0,0174; k_{ng}=0,0936; r=0. The last value of r reflects the final stage of the process.

To assess the accuracy of the identification, a statistical study was conducted with an imitation of the inaccuracy of measuring the temperature under the normal law with a dispersion of 2 °C. Average valuation errors tend to zero, which indicates the validity of the valuations. The average absolute errors are: $\delta g=7\%$; $\delta k_{nm}=13\%$; $\delta k_{mg}=15\%$; $\delta k_{ng}=13\%$.

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The results obtained show a certain feasibility of a separate (autonomous) heat-transfer process aspects in order to develop a constructive heat-sink design

III. CONCLUSIONS

For a two-phase presentation of the flow management arrangement, mathematical descriptions of direct and flow-through interactions in the process of drying liquid and air flows without taking into account the heat are provided.

The iterative and analytical methods for solving heat balance control systems have been implemented, from which it follows that the speed of calculations by using approximately one order is ensured.

To determine the numerical values of the parameters of the mathematical model for the experimental data obtained by Matlab, programs for evaluating the minimization of the rate of separation of the vectors corresponding to the experiment were compiled. The identification accuracy was assessed by computer-aided statistical statistical tests of the corresponding errors in the conditions of experimental temperature measurements. Evidence of the viability of the value of the efficiency (accuracy) of the developed methods is given.

Reliable data were obtained on the preference of a direct flow control, from the point of view of the uniformity of the conditions of the drying process of vegetable medicinal materials by

A three-phase mathematical model with an iterative solution scheme has been compiled, in which case the calculation is carried out sequentially in the direction of flow flows.

Poluchennye numerical Articles Poll kinetic and regime parametrov pozvolyayut oharakterizovat oblast issledovany nA baze poluchennoy adekvatnoy matematicheskoy modeli vzaimodeystviya faktorov, vytekayuschih of konstruktivnogo oformleniya ratsionalnogo kontakta potokov faz, rezhimov osuschestvleniya protsessa and influence nA profili temperatury Po poddonam.

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