International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

RESEARCH OF THE TEMPERATURE FIELD PROFILES OF THE DRYING PROCESS OF PLANT RAW MATERIALS USING A SOLAR-WATER HEATING DRYING EQUIPMENT

[1]Sh. A. Sultanova,[2]J. E. Safarov,[3]G. T. Dadayev,[4]B. M. Jumayev

ABSTRACT--*This research of the profiles of the temperature field of the process of convective drying of plant raw materials. Mathematical modeling of the temperature field on the basis of the three-phase flow structure was carried out. In a wide range of variation of design and operating parameters (from 50 to 150%) their nominal values are identified. A qualitatively new picture of the temperature field was found, which is expressed in the fact that, depending on the contact conditions of the gas and solid phases and the relative air flow, the temperature profile on the pallets can have both positive and negative slopes. The sensitivity of this relationship, formalized in the form of axonometric graphs and the corresponding families of isolines on the plane of variable factors, is shown. Criteria for non-uniformity of temperature profiles across pallets (dispersion of material temperature and angle of inclination of the approximating straight line with fixed values of the average temperature of the substance) are proposed. The procedure for solving the optimization problem on the conditions of the minimum criterion for the unevenness of the material profile is justified when the average temperature of the material specified in accordance with the conditions of the process schedule is restricted as equality.*

Key words*-- drying, temperature, raw materials, drying.*

I. INTRODUCTION

In the world, 40% of medicinal raw materials are obtained from plants for the pharmaceutical industry. At the same time, today about 60% of medicines consist more or less of plant substances. In accordance with this, the process of manufacturing the necessary plant materials for the production of pharmaceuticals has the scientific and practical importance of introducing modern and intensive methods of technology as well as devices.

[1]*PhD, assistant professor, Head of department, Tashkent state technical university named after Islam Karimov, str. University 2, Tashkent, 100095 Uzbekistan,sh.sultanova@yahoo.com*

[2] *DSc, professor, Dean of the Faculty of* machine *building, Tashkent state technical university named after Islam Karimov, str. University 2, Tashkent, 100095 Uzbekistan,jasursafarov@yahoo.com*

[3] *PhD, Deputy Dean of the Faculty of machine building, Tashkent state technical university named after Islam Karimov, str. University 2, Tashkent, 100095 Uzbekistan,dadayev1982@yandex.ru*

[4] *Researcher, Tashkent state technical university named after Islam Karimov, str. University 2, Tashkent, 100095 Uzbekistan bjumaev7777@gmail.com*

Drying is one of the most advanced and commonly used preservation methods. It consists of the removal of moisture from the product, resulting from the simultaneous process of heat and mass transfer through the use of heat. The drying process can affect (partially or completely) product quality in terms of sensory, nutritional and functional characteristics. For a successful drying operation, it becomes necessary to choose a suitable technique, especially for valuable products, including medicinal plants.

Scientists study determination of temperature and concentration of a vapor-gas mixture in a wake of water droplets moving through combustion products [1], hydrodynamics and mass-transfer characteristics analysis of vapor–liquid flow of dual-flow tray [2], mechanism of heat transfer in heterogeneous droplets of water under intense radiant heating [3], a model of heat and mass transfer in gas phase in axial and turbulent dispersed annular flows [4].

In the work of A.B. Sukhotskii et al. [5], an experimental study and generalization of data on the intensified convective heat transfer of single-row finned tube bundles in air flow was investigated. The results of an experimental study of the intensified convective heat transfer of a single-row beam consisting of bimetallic finned tubes in a stream of heated air are presented as dependencies of the Nusselt number on the Grashof and Reynolds numbers.

In the work of V.A. Sychevsky et al. [6] investigates the aerodynamics of an experimental stand for drying the Institute for heat and mass transfer named after A.V. Lykov of the National Academy of Sciences of Belarus. The geometric structure of the wood drying bench is complex. Therefore, the calculation of the aerodynamics of the drying agent in the chamber is carried out on the basis of the ANSYS Fluent 14.5 software package. On the basis of the calculations performed, an analysis of the structure of the flow of the drying agent was carried out, and stagnant zones were revealed. It is established that the wood-drying bench does not work in the optimal aerodynamic mode. In [6-7] it was shown that vortices are formed at the front and rear edges of the boards arranged in a line in a stack, which adversely affect the aerodynamics of the flow and the processes of heat and mass transfer in the stack. In the drying chamber, the air flow overcomes a number of local resistances caused by the presence of a heat exchanger, a fan, a stack, and the geometry of the dryer (changing the direction of air flow).

Experimental investigation of bound and free water transport process during drying of hygroscopic food material [8]. It is interesting to highlight that the cell membranes rupture at different stages of drying rather than collapsing at one time. The membrane collapse depends predominantly on the penetration rate of heat energy and the pressure gradient between intracellular and intercellular environments. All test results suggest that most of the cell membranes rupture at the middle stage of drying where the moisture content is about 2-4 kg/kg (db.). Furthermore, the moisture distribution profile confirmed that some moisture remained around the centre of the dried sample although the surface of the sample became dry [8].

In the study mathematical simulation of convective drying: spatially distributed temperature and moisture in carrot slab [9], experimental study and analysis on heat transfer effect of far infrared convection combined drying [10], next generation drying technologies for pharmaceutical applications [11], heat and mass transfer parameters in the drying of cocoyam slice [12], mathematical modelling of convective drying of feijoa (Acca sellowiana Berg) slices [13], wheat convective drying: An analytical investigation via Galerkin-based integral method [14], research authentication of the medical plants by multispectral analysis [15], development of helio of a drying equipment based on theoretical researches of heat energy accumulation [16-17].

In the article [18] study, intensification of the plant products drying process by improving solar dryer design, as a result, graphical interpretations of isolines of drying agent flow are obtained and location of passive zones in the dryer chamber are identified. Uniformity of the temperature zones in the chamber is ensured by supplying additional drying agent into the passive zones. Temperature values at various levels of the drying chamber are experimentally obtained. Results for drying cut-up mass of vegetables and fruits are presented.

Experimentation. Development of a water-heating convective drying equipment for medicinal herbs with their medicinal properties at low temperatures without using electricity, providing the ability to predict changes in temperature and moisture content in the layer of dehydrated material, as well as knowledge of the time required to obtain the desired final values of temperature and moisture content. The solution of these problems determines the prospects of the drying process with obtaining a quality product at low cost and loss of raw materials.The basis for obtaining a quality product is technological systems that have a complex structural and functional organization. As a rule, the control objects in these systems are specific technological processes.

High-quality drying of thermolabile products related to medicinal herbs should be carried out strictly controlling and regulating all process parameters, including the temperature of the dehydration objects. It is not experimentally possible to determine the temperature fields in the hovering fine particles with a significant intensity of the drying process. As a consequence, it is obvious that it is necessary to implement a mathematical model of heat and mass transfer in order to calculate temperatures at each spatial point of sputtered particles of dehydrated materials during the drying process in order to identify and implement rational modes and control product quality. When introducing rational modes and structures of drying apparatus, in the first place, it is necessary to ensure in practice the conditions for obtaining the required technological characteristics of the material being dried.

Based on the analysis of the technological situation conducted by the author, as variable factors, we choose the relative air flow through the drying unit and the coefficient expressing the intensity of heat exchange between the gas phase and the material being dried. At the same time, the remaining parameters expressing design and operational features are assumed to be unchanged. The range of variation is taken equal to 0.5 to 1.5 of their nominal values.

Accepted nominal values of parameters:

gnom=.38;

Tn0=100;

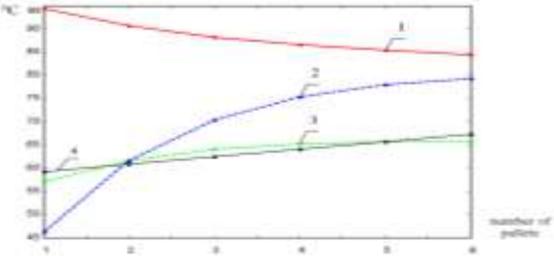
Tg0nom=20;

knmnom=.025;

kmgnom=.0135;

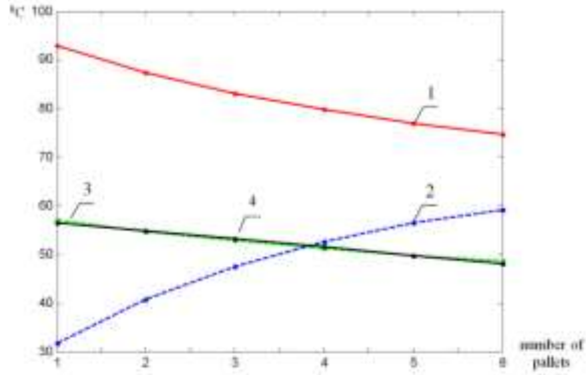
kngnom=.1;

The individual results shown in Fig. 1-2 show that the temperature profile of the material along the height can be both increasing and decreasing.



1 is the temperature of the coolant; 2-temperature gas phase; 3-temperature profile for the material; 4-results of theoretical studies.

Figure 1: Mode with a positive slope of the temperature profile



1-temperature of the coolant; 2-temperature gas phase; 3-temperature profile for the material; 4-results of theoretical studies.

Figure 2: Mode with a negative slope of the temperature profile

As a criterion for the uneven distribution of temperature across the pallets, along with the average temperature (t_{sr}), we take the variance of the temperature $t_{dis}T$ and the proportionality coefficient in the linear approximation formula for the temperature profile.

The results of studies in these ranges are shown in Fig. 3-6.

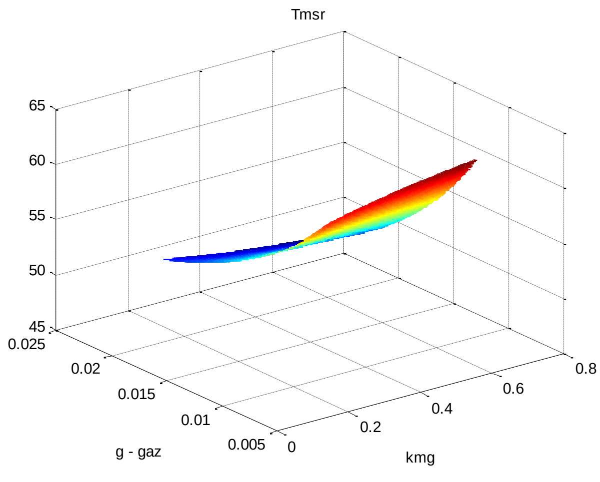


Figure 3: Average values of material temperature by pallet

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

As a result of the experiments, criteria were found for the non-uniformity of the temperature profiles across the pallets of the material temperature dispersion and the slope angle of the approximating straight line for fixed values of the average temperature of the substance.

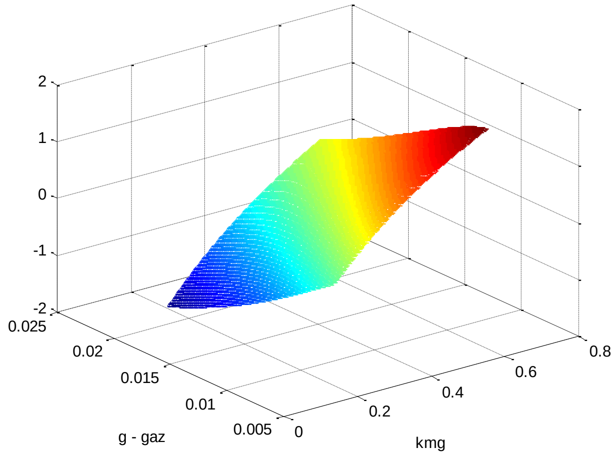


Figure 4: Surface expressing positive and negative values of the slope of the temperature profile

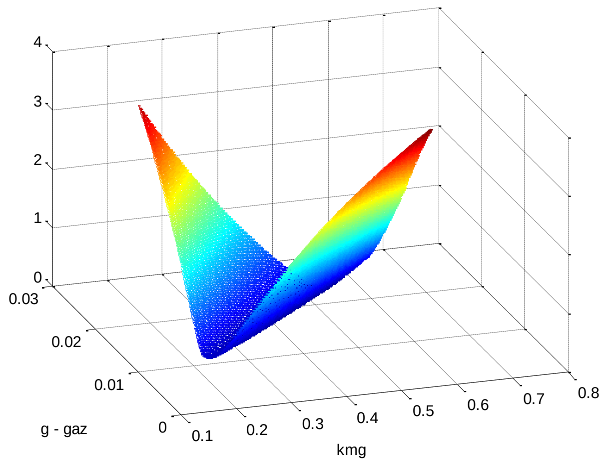


Figure 5: The surface of the criterion $T_{dispersiya}$

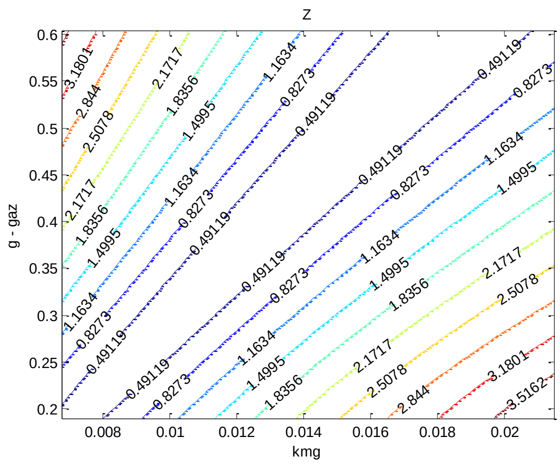


Figure 6: Isolation $T_{dispersiya}$

Development of recommendations for optimal process management

Received: 02 Jan 2020 | Revised: 12 Feb 2020 | Accepted: 17 Mar 2020

The relationship between the criteria for uneven profiles has a partial interdependence. In particular, the temperature dispersion and the angle of inclination of the aligned profile are almost correlated, but unlike the angle of inclination, which may be zero, which is ideal for drying, from the point of view of the same profile along the pallets, the dispersion has a certain hysteresis zone. This is consistent with the fact that there always remains some residual irregularity, which can be observed with an increase in the number of scans (Fig. 7).

In practice, designing not only dryers, but also devices with interphase exchange, it becomes necessary to select variable optimizable variables, based on the requirements of equality of the average temperature to a certain value specified in accordance with the technological regulations and to ensure minimum slope.

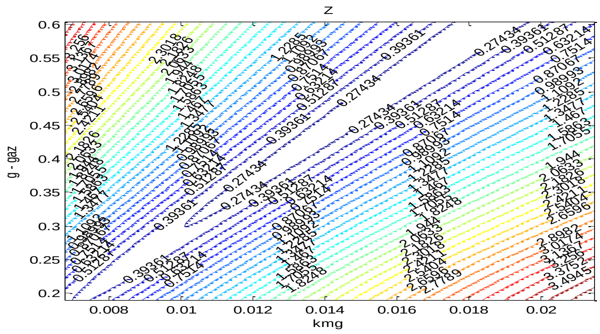


Figure 7: Zone with minimum bottom for dispersion values

Sometimes a situation arises of the need to provide some compromise between these indicators, in terms of energy efficiency.

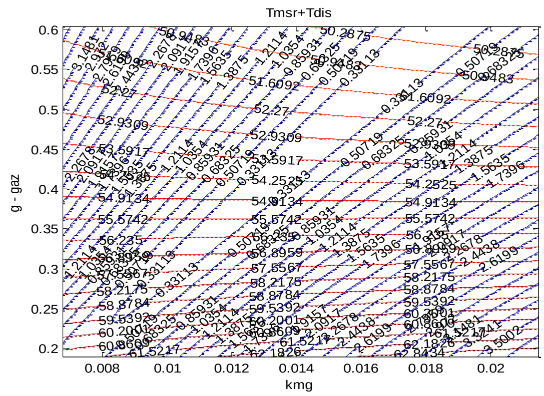


Figure 8: Nomogram for calculating a given temperature profile

In addition, the nomogram allows you to select the appropriate values of the parameters of the technological mode and the conditions of the contact phase (with increasing or decreasing nature) (Fig. 9).

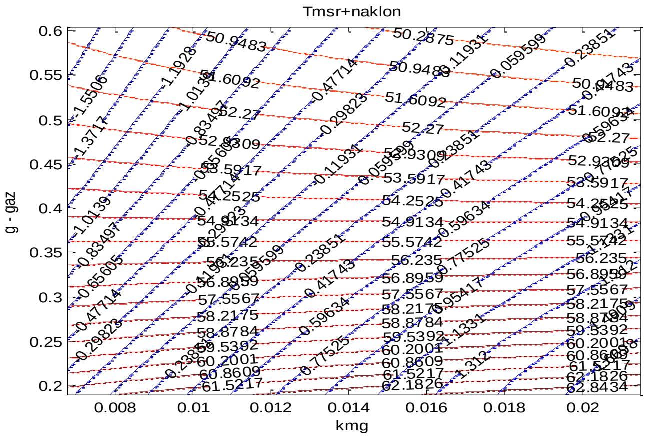


Figure 9: Nomogram to determine the optimal T_{sr} and slope (b_{mnk})

For a more accurate calculation of the optimal parameters, an algorithmic procedure was developed on Matlab:

```
global n Tn0 Tg0 knm kng r Tt
n=6;
gnom=.5;
Tn0=100;
Tg0=20;
knm=.025;
kmgnom=.015;
kng=.1;
r=0;
za0=[3.78 -.0182];
za2=fminsearch(@z170401L,za0,[0 1e-7 1e-7 5000])
za2=fminsearch(@z170401L,za2,[0 1e-7 1e-7 5000])
function FF=z170401L(aaa)
global n Tn0 Tg0 knmkng r Tt
g=aaa(1);
kmg=aaa(2);
parametri=[n Tn0 Tg0 g knmkmgkng r];
Tt=sushilka3f(parametri);
Tm=Tt(2,:);
Tmsr=mean(Tm);
disTm=std(Tm);
np=1:6;
pr=Tm;
np100(1:n)=ones;
    NP=[np' np100'];
bmnk=regress(pr',NP);
```

```
prmnk=NP*bmnk;
naklon=bmnk(1);
L=(naklon)^2+100*(Tmsr-85)^2;
FF=L;
```

The program implements the solution of the problem of finding the conditional extremum with the restriction in the form of equality to the average temperature given by the method of penalty functions.

The above procedure for r=0 gives optimal, g_{otimal}=1.2857, $kmg_{optimal}$=0.032, and for r=0.725, we get g_{otimal}=0.3832, kmg=0.0126, which is in good agreement with the above nomogram (Fig. 8).

The above-mentioned relationship between the criteria of unevenness is clearly manifested when comparing optimization options according to different criteria. For the conditions of solving an optimization problem by the criterion of minimizing the square of the slope, minimization of the material temperature by the dispersion gives minor deviations:g_{otimal}=0.3833, $kmg_{optimal}$=0.0124

II. CONCLUSION

Mathematical modeling of the temperature field on the basis of the three-phase flow structure was carried out. In a wide range of variation of design and operating parameters (from 50 to 150%) their nominal values are identified.

A qualitatively new picture of the temperature field was found, which is expressed in the fact that, depending on the contact conditions of the gas and solid phases and the relative air flow, the temperature profile on the pallets can have both positive and negative slopes. The sensitivity of this relationship, formalized in the form of axonometric graphs and the corresponding families of isolines on the plane of variable factors, is shown.

Criteria for non-uniformity of temperature profiles across pallets (dispersion of material temperature and angle of inclination of the approximating straight line with fixed values of the average temperature of the substance) are proposed.

The procedure for solving the optimization problem on the conditions of the minimum criterion for the unevenness of the material profile is justified when the average temperature of the material specified in accordance with the conditions of the process schedule is restricted as equality.

REFERENCES

1. Antonov, D. V., Kuznetsov, G. V., Strizhak, P. A. Determination of temperature and concentration of a vapor–gas mixture in a wake of water droplets moving through combustion products. J. Engin. Therm., 2016, vol. 25, No 3, pp. 337–351.
2. Zhang, L., Li, Z., Yang, N., Jiang, B., Pavlenko, A. N., Volodin, O. A. Hydrodynamics and mass-transfer characteristics analysis of vapor–liquid flow of dual-flow tray. J. Engin.Therm., 2016, vol. 25, No. 4, pp. 449–463.
3. Vysokomornaya, O. V., Piskunov, M. V., Kuznetsov, G. V., Strizhak, P. A. Mechanism of heat transfer in heterogeneous droplets of water under intense radiant heating. J. Engin.Therm., 2017, vol. 26, No. 2, pp. 183–196.

4. Laptev, A. G. and Lapteva, E. A. A model of heat and mass transfer in gas phase in axial and turbulent dispersed annular flows. J. Engin. Therm., 2018, vol. 27, No. 1, pp. 45–50.
5. Sukhotskii, A. B. and Marshalova, G. S. Intensified convection heat transfer of single-row bunch of finned tubes in an air stream: experimental study and generalization of the obtained data. Energetika. Proc. CIS Higher Educ. Inst. and Power Eng. Assoc., 2018, vol. 61, No 6, pp. 552–563.
6. Sychevsky, V. A., Chorny, A. D., Baranova, T. A. Optimization of aerodynamic conditions of the chamber drier operation. Energetika. Proc. CIS Higher Educ. Inst. and Power Eng. Assoc., 2016, vol. 59, No 3, pp. 260–271.
7. Sun, Z. F. Numerical simulation of flow in an array of in-line blunt boards: mass trans- fer and flow patterns. Chem. Engin. Sci., 2001. vol. 56, No 3. pp. 1883–1896.
8. Khan, M. I. H, Mark, W. R., Szilvia, A. N, Joardder, M. U. H, Karim, M. A. Experimental investigation of bound and free water transport process during drying of hygroscopic food material. Inter. J. Ther. Sci., 2017, vol. 117, pp. 266-273.
9. Barati, E. and Esfahani, J. A. Mathematical simulation of convective drying: spatially distributed temperature and moisture in carrot slab. Int J Therm Sci., 2012, vol. 56, pp. 86-94.
10. Liu Chunshan, Sh. T., Yang, Sh., Wu, W., Chen, S. Experimental study and analysis on heat transfer effect of far infrared convection combined drying. 2017 International Conference on Smart Grid and Electrical Automation (ICSGEA). China.
11. Walters, R. H., Bhatnagar, B., Tchessalov, S., Izutsu, K.I., Tsumoto, K., Ohtake, S. Next generation drying technologies for pharmaceutical applications. J. Pharm. Sci. 2014, vol.103, No. 9, pp. 2673-2695.
12. Ndukwu, M. C., Dirioha, C., Abam, F. I., Ihediwa, V. E. Heat and mass transfer parameters in the drying of cocoyam slice. Case Studies in Ther.Engin., 2017, vol. 9, pp. 62-71.
13. Castro, A. M., Mayorga, E. Y., Moreno, F. L. Mathematical modelling of convective drying of feijoa (Acca sellowiana Berg) slices. J.Food Engin., 2019, vol. 252, pp. 44-52.
14. Santos, J. P. S., Santos, I. B., Pereira, E. M. A., Silva, J. V., Barbosa, De Lima A.G. Wheat convective drying: An analytical investigation via Galerkin-based integral method. Defect and Diffusion Forum., 2015, vol. 365, pp. 82-87.
15. Safarov, J. E., Sultanova, Sh. A., Dadayev, G. T., Samandarov, D. I. Method for the primary processing of silkworm cocoons (Bombyx mori). International Journal of Innovative Technology and Exploring Engineering. vol.9, Issue-1, 2019. pp.4562-4565.
16. Safarov, J. E, Sultanova, Sh. A., Dadaev, G. T. Development of helio of a drying equipment based on theoretical researches of heat energy accumulation. Energetika. Proc. CIS Higher Educ. Inst. and Power Eng. Assoc., 2020, vol. 63, No 2. pp.174-192.
17. Safarov, J. E., Sultanova, Sh. A., Dadayev, G. T., Samandarov, D. I. Method for drying fruits of rose hips. International Journal of Innovative Technology and Exploring Engineering. vol. 9, Issue-1, 2019. pp.3765-3768.
18. Khazimov, M. Zh., Khazimov, K. M., Urmashev, B. A., Tazhibayev, T. S., Sagyndykova Zh. B. Intensification of the plant products drying process by improving solar dryer design. J. Engin. Therm., 2018, vol. 27, No. 4, pp. 580–592.