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Analysis of the Results of Research on Spray Drying of Starch Suspension

The spray dryer is very often applied in chemical and food - processing industries. This drying method includes suspension - spraying with the contents about 30 to 65% of dried substance. The drying period in most cases is only several seconds. The drying agent is the warm air. A model of momentum, heat and mass transfer in the atomization - swirler zone was proposed. To verify the model an extensive experimental investigation was performed on water evaporation at different initial air temperatures, feed rates, flow rates of the drying agent and different parameters of atomization and initial particle size distribution. Good agreement between experimental results and theoretical data was achieved. The model was verified experimentally on the basis of results of investigations on drying of a 40% mass solution of starch and water.

Keywords: *Spray, Dryer, Starch, Drying,Temperature*

1. INTRODUCTION

Different suspension of certain products react with uneven drying, which depends on the properties of the material that is dried. It is very difficult to recommend a unique tec–hnique of the spray driers. In comparison with other sys–tems, spray drying requires a relatively small storage space. Service and maintenance are very simple and is perfor–med with little labor. These advantages, as well as a eco–nomical heat transfer provides the optimal cost of the final dried product. Drying time is often only a few seconds, and can successfully dry heat sensitive products such as vita–mins, chemical and food products and other, which better submit to a high temperature in a short period of time, but to lower temperatures for a longer period of time [1-3].

For substances such as suspension of various materials with over 30 to 65% of dry matter, spray drying kilns is quality solution to the problem of drying. There have been many attempts at formulating a mathematical description of spray drying since the 1950s. In spray drying there are many phenomena, which are difficult to represent in the form of a mathematical model. For many years polydispersity of spray, entrainment effects, or problems of internal heat and mass transfer in the disperse phase have been inadequately considered in such models. Practically, models of the process that have been created since the beginning of the 1970s were concerned only with the plug flow of a drying agent [4-6]. Drying systems based on the principle of heat transfer by convection, such as spray driers and pneumatic dryer have been treated in the literature [7-14].

2. EXPERIMENTAL APPARATUS AND DETAILS AIN HEADING

Inlet air drying is done by fans (3). Air over the absor–ptive heater (4), with the help of fans (3). Thermal po–wer heater (4), can be regulated in the range of 40 to 65 kW. The drying material is led through the entrance (6). Material for drying - (40% mass solution of starch and water), is emptied into the atomizer (7).

Table 1. The basical characteristics of the spray drying chamberseading

Name	Units	Dimensions
Diameter chamber spray dryer Elevation spray drying chamber	(mm) (mm)	5000 5500
Cyclone diameter	(mm)	1400
Power fan Air flow	(kW) (m^3/h)	18.5 9750 - 14400
Atomizer (swirler) Electric motor rpm	 (kW) (min^{-1})	 0.75 3800

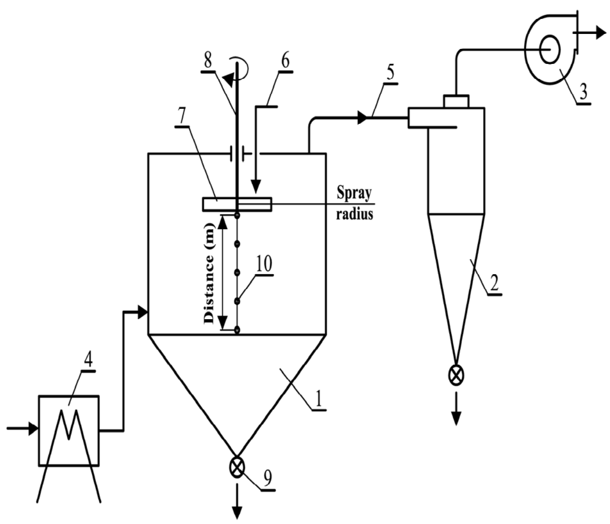

Figure 1. Schematic of the experimental plant spray dryer: 1-chamber spray dryer, 2-cyclone, 3-fan, 4-heater, 5-air outlet, 6-supply of material, 7- swirler (atomizer), 8-drive axle, 9 – rotary feeder, 10 - measuring pointstle

Axle (8), is given by electric propulsion. Spray nozzle rotates at a large number of rpm n = 3800 min^{-1},

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and thus has made dispersal of the liquid solution in small droplets. Aerosols are derived in the form of a rotating disc diameter of 320 mm, with a paddle. Extensive spray speed is 63.5 ms^{-1}.

In contact with hot gas – air drying is done in dispersed droplets and intensive exchange of heat and mass is carried out. Air flow to the fan (3), can be regu–lated, so that it can be achieved at the drying air velocity of V = (0.17 to 0.24) ms^{-1}.

Dried material is using a rotary feeder (9), and transported as a finished product. Air with dust particles is drained with piping (5) and the cyclone (2). The cyclone (2), the complete separation, after which they are using fans (3), is performed by taking the air into the atmosphere.

3. EXPERIMENTAL RESULTS AND DISCUSSION

One of the main sources of error in spray drying simulation is an imprecise specification of initial process parameters, for example, spray cone angle and particle size distribution.The parameters were carefully determined for each swirl insert and for each feed rate.

Experimental investigations of water evaporation were carried out for three feed rates (98, 135, 157 kg h^{-1}), three values of air temperature (80, 100, 130 oC). An example of the initial particle size distribution obtained at feed rate of 98 kg h^{-1} is shown in Figure 2.

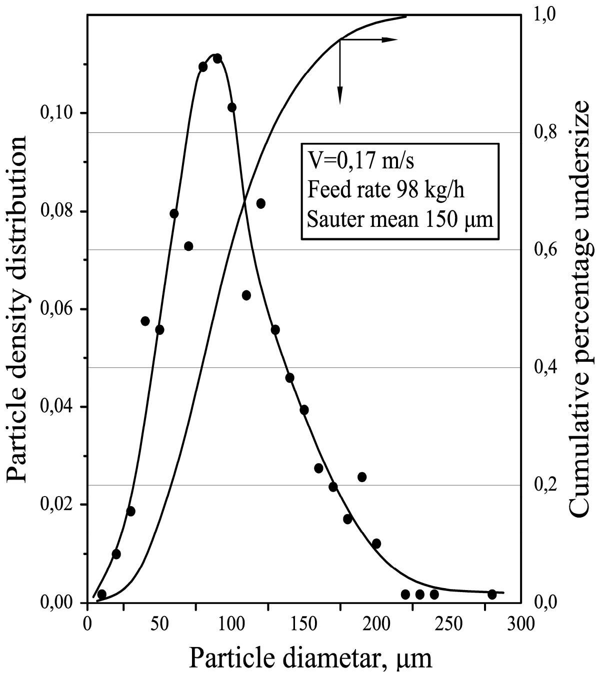

Figure 2. Initial particle size distribution

Both in this case and for other values of initial atomization parameters a characteristic log-normal part–icle size distribution was obtained. The experimental investigations show that the character of the distribution does not change as a function of the distance to the atomizer - swirler in all experimental runs.

All theoretical calculations made negligible changes in the air and material temperature in cross-section of atomized material spray, which was confirmed experi–mentally.

Increasing temperature in the cross section spray dryer is slightly, Figure 3. The absence of an air tempe–rature gradient in the spray cross-section can be expla–ined by the design of the experimental set-up and by the process parameters. The air velocity profile in the tunnel of a dryer is flat and the turbulence is low. In the study carried out by [15, 16] a temperature distribution along the spray dryer radius was observed, and obtained similar results.

As simulation calculations show, the particle of a diameter corresponding to 95% cumulative percentage undersize did not contact the walls of the tunnel dryer, which was in agreement with experimental observations (in all experimental trials no wetting of the tunnel wall was reported).

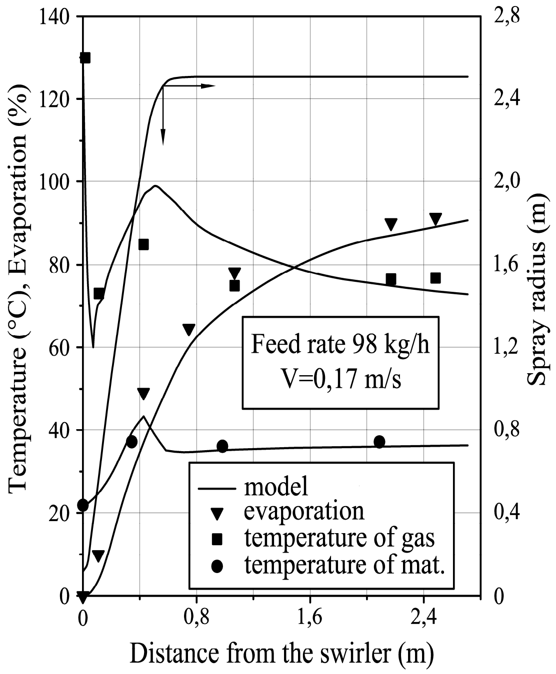

Figure 3. Comparison of theoretical and experimental results Initial particle size distribution

Fig. 2, shows a comparison between the theoretical and experimentally calculated changes in the temperature of air, material and evaporation rate as a function of the distance from the atomizer for the same feed rate and air flow velocity. A theoretically calcu–lated spray radius is also plotted on the same graph. A rapid drop in the air temperature and then its charac–teristic rise are related to entrainment effects.

An increase in the amount of air in the spray caused by its expansion causes the temperature to rise despite intensive evaporation, until the moment when a balance occurs between the heat used for evaporation and the heat supplied into the spray by the entraining air.

After this time, a drop in the air temperature as a function of the distance to the atomizer is observed. Similar profiles of particular functions were obtained in many studies [17-19].

Experimental results, shown in Figure 4, illustrate changes in the evaporation rate along the tunnel of a dryer for different temperatures of the drying agent. Air temperature has a decisive effect on the evaporation rate. No significant influence of the drying agent velo–city on the shape of the curves discussed was observed. Particles achieve a zero relative velocity after a short period of time which limits convective heat transfer between the continuous and disperse phases.

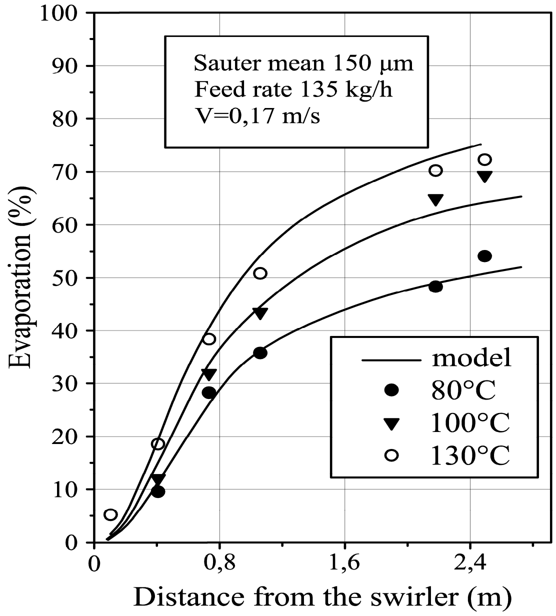

Figure 4. Evaporation at different air temperatures

Lack of air circulation zones in the tunnel causes the spray to compact and move parallel to the tunnel of dryer walls. Very good agreement between theoretical and experimental results is worthy of note.

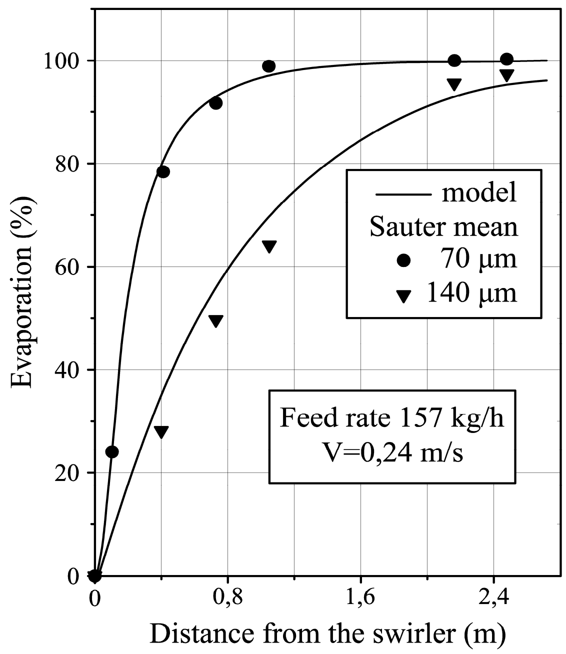

Figure 5. Effect of sauter mean on evaporation rate

The final figure discussed, Figure 5, shows the effect of the initial particle size distribution on the evaporation rate at the same air temperature and feed rates.

The analyses of the results show that the character of initial particle size distribution has a remarkable influ–ence on the whole evaporation process. Particles with a smaller Sauter mean diameter are evaporated much faster than particles having larger mean diameters.

In the case where the initial particle size distributions are similar, the feed rate is the parameter that determined the evaporation rate [20]. Good agreement between theoretical and experimental results was also obtained in this case.

4. CONCLUSIONS

As part of this work the experimental and theoretical study of spray drying for drying starch solution was carried out. Comparison of theoretical and experimental results was performed. It shows the evaporation at different temperatures. It also shows the influence of particle size on the intensity of evaporation.

Determined parameters of drying regime on the basis of research of operating conditions, can be consi–dered optimal parameters, given that the experimental drying process produced good quality of dried material.

The model presented in this paper can be used to predict many subtle phenomena that occur during spray drying, in particular in complex air flow. In all theo–retical simulations of the drying process of evaporation, a reasonable agreement with the experimental data was reached.

The research results have practical value, because it is based on experimental data. In this way, the research results can be useful for researchers, designers, produ–cers and users of these and similar drying systems.

REFERENCES

[1] Bellinghausen, R., Esper, G.J and Gehrmann, D. :Scale-up of spray driers on the basis of laboratory scale experiments, Meet. of the EFChE Drying Working Party, Utrecht, 1993.

[2] Langrish, T.A.G. and Zbiciński, I. : The effects of air inlet geometry and spray cone angle on the wall deposition rate in spray dryers, Trans.Inst. Chem. Eng., 72 (A), p. 420-430, 1994.

[3] Larrgrish, T.A.G., Oakley, D.E., Keey, R.B., Bahu, R.E. and. Hutchinson, C,A.: Time-dependent flow patterns in spray dryers, Trans. Inst. Chem. Eng., 71 p.355-360, 1993.

[4] Indarto, A., Halim, Y., Partoputro, P. : Pneumatic Drying of Solid Particle: Experimental and Model Comparison, Experimental Heat Transfer*,* Vol.20, pp.277-287, 2007.

[5] Islam, M., Marks, B., Bakker – Arkema, F.: Opti–mization of commercial ear-corn dryers, Agricul–tural Engineering International the CIGR E-journal*,* Vol.VI, pp.15-22, 2004.

[6] Prvulović, S., D. Tolmač, D., M. Lambić, M.: Determination of energetics characteristics of con–vection drying place on pneumatic transportation material. Journal Process Technique*,* No.1, pp.70-74, SMEITS, Belgrade, 2001.

[7] Tolmac, D. : *Introduction to the Theory of Drying with Examples from Practice*, Technical Faculty, Zrenjanin, Serbia, 2007.

[8] Prvulović, S., Tolmač, D., Lambić, M.: Convection Drying in the Food Industry, Agricultural Engi–neering International the CIGR E-journal, Vol.IX, pp.1-12. 2007.

[9] Prvulović, S., Tolmač, D., Radovanović, Lj.: Rese–arching results energetics charakteristics convection drying, Strojniski Vestnik (Journal of Mechanical Engineering), Vol.54, No.9, pp.639/644, 2008.

[10] Tolmač, D.: Analysis of economic work of convec–tion starch dryers. Journal Process Technique, No.1, pp.20-22, SMEITS, Belgrade, 1992.

[11] Miura, T., Othani, S. and Maeda, S.: Heat and mass transfer to and from sprays, in A.S. Mujumdar (ed.), Drying'80, Vol. 1, Hemisphere, McGraw Hill, New York, NY, p. 351-356, 198.

[12] Oakley, D.E. and Bahu, R.E.: Spray/gas mixing behaviour with spray dryers, in A.S.Mujumdar and I. Filkova (eds.), Drying 9.1, Elsevier, Ams–terdam, p. 303-313, 1990.

[13] Papadakis, S.E. and King, C.J.: Air temperature and humidity profiles in spray drying. 1. Features predicted by the particle source in cell model, 2. Experimental measurements, Ind. Eng.Chem. Res., 27 (11) p. 2111-2123, 1988.[14] Prvulovic, S., Tolmac, D., Blagojevic, Z. : Experimental research on energetic charakteristics of starch dryer, FME Transactions, 37 (1) p.47-52, 2009.

[14] Tolmač, D.: Systems energetic parameters for starch drying in grain industry. Journal of Energetic Technologies, No.2, pp.11-13, Serbia Solar, 2005.

[15] Tolmač, D. et al.: Effect of heat transfer on convec–tion dryer with pneumatic transport of material, FME Transactions, Vol.36, No.1, pp.45-49, Facu–lty of Mechanical Engineering, Belgrade, 2008.

[16] Tolmač, D., Prvulović, S., Blagojevic, Z.: Energy parameters for drying starch in the grain processing industry, Journal of Energetic Technologies, No, 1-2, pp. (11-13), Serbia Solar, 2005.

[17] Verdijch, G.J.C., Weiss, M., Presig, H.A.: Model–ling of a pneumatic dryer for potato starch, Journal of Food Engineering, Vol. 37, pp.243-258, 1998.

[18] Indarto, A., Halim, Y., Partoputro, P. : Pneumatic Drying of Solid Particle: Experimental and Model Comparison, Experimental Heat Transfer, Vol.20, pp.277-287, 2007.

[19] Tolmac, D., Prvulovic, S., Radovanovic, Lj.: (2008) Effect of Heat Transfer on Convection Dryer with Pneumatic Transport of Material, FME Transac–tions, Vol.36, No.1, p.45-49, Faculty of Mechanical Engineering, Belgrade, 2007.

АНАЛИЗА РЕЗУЛТАТА ИСТРАЖИВАЊА НА СПРЕЈ СУШАРИ ЗА СКРОБНЕ СУСПЕНЗИЈЕ

Д. Толмач, С. Првуловић, Ј. Толмач, С. Станков

Спреј сушаре се врло често користе у хемијској и прехрамбеној индустрији. Ова метода укључује су–шење суспензија са садржајем 30-65% суве матери–је. Период сушења је у већини случајева само неко–лико секунди. Агенс сушења је топли ваздух. Пред–ложен је модел преноса топлоте и масе у зони ато–мизације. Да би се проверили модели, извршено је експериментално истраживање испаравања воде на различитим температурама, капацитетима и про–току агенса сушења при различитим параметрима атомизације и почетне расподеле величина честица. Добијено је добро слагање између експериментал–них резултата и теоријских поставки. Модел је екс–периментално верификован на основу резултата истраживања при сушењу 40%, масеног раствора скроба и воде.