Prosimy cytować jako: Inż. Ap. Chem. 2010, 49, 4, 62-63

Julia RABAEVA, Ireneusz ZBICIŃSKI

e-mail: julia@wipos.p.lodz.pl

Department of Heat and Mass Transfer, Faculty of Process and Environmental Engineering, Lodz Technical University, Lodz, Poland

Gas-admixing foam spray drying of skin-forming and porous materials

Introduction

Foam spray drying is a process of introducing gas into the feed before or during spray drying in order to process hard-to-dry food materials and semi-products which are the mixture of biological substances such as protein, fat, vitamins and mineral components difficult to dry in a standard spray drying system, e.g. in meat, detergents and pharmaceutical industries.

Gas-admixing foam spray drying is one of the methods of feed foaming. In the gas-admixing method, the foaming gas (e.g. N_2, CO_2) is injected at high pressure between the pump and atomizer. In the literature, there have been a few papers on foam spray drying since 1961 when for the first time *Hanrahan* and *Webb* applied foamed feed to spray dry acid cottage cheese whey [1], skim milk [2] and whole milk [3].

The spray-dried material can be divided into three groups: skin-forming, agglomerate and crystalline materials [4, 6]. The properties of dry powder belonging to each group depend on the physical properties of the material and operating parameters of drying and atomization. According to the literature, particles of skin-forming materials are most frequently spherical, filled with gas, while particles of the agglomerate-like material have a porous structure [5, 6].

The main purpose of the paper was to compare the effects of feed foaming on final product properties of skin-forming and porous materials. To meet the aim of the project extensive experiments on the effects of feed rate and admixed gas flow rate on particle size distribution, porosity and other final product properties were performed in a co-current spray drying tower.

Material and methods

All drying experiments for gas-admixing foaming method were performed for 20% maltodextrin (skin-forming material) and detergent (porous material) solutions with a small addition of a surfactant to the maltodextrin solution (GMS up to 2%). Nitrogen (N_2) injected to the solution between the pump and atomizer was used for feed foaming. The quantity of injected gas was measured by a gas flow meter installed before the mixing device. The feed flow rate and density of the solution were also measured. Parameters of the feed and gas flow for selected spraying experiments are shown in Table 1.

Tab. 1. Parameters of drying process

Test number	Temperature [°C]	Air flow rate [Nm^3/h]	Feed flow rate [kg/h]	Foaming flow rate [g/h]		Pressure of atomization [bar]	
				Maltodextrin	Detergent	Maltodextrin	Detergent
Test 1	200	300	9	0	0	7.2	13.5
Test 2				14	16	7.9	15
Test 3				40	42	8.5	16
Test 4	200	300	14.5	0	0	21.8	20
Test 5				21	22	20.2	21
Test 6				75	75	22	23

Experimental equipment

The experiments were carried out in a 9 m long cocurrent spray drying tower equipped with feeding, heating and product collecting systems (Fig. 1) [7]. Each part of the measuring section was equipped with optical glass windows to observe the atomization process and to perform drying kinetics measurements. The column was equipped with a data acquisition system which allows us to observe and control drying of the foaming gas and feed parameters during the drying process.

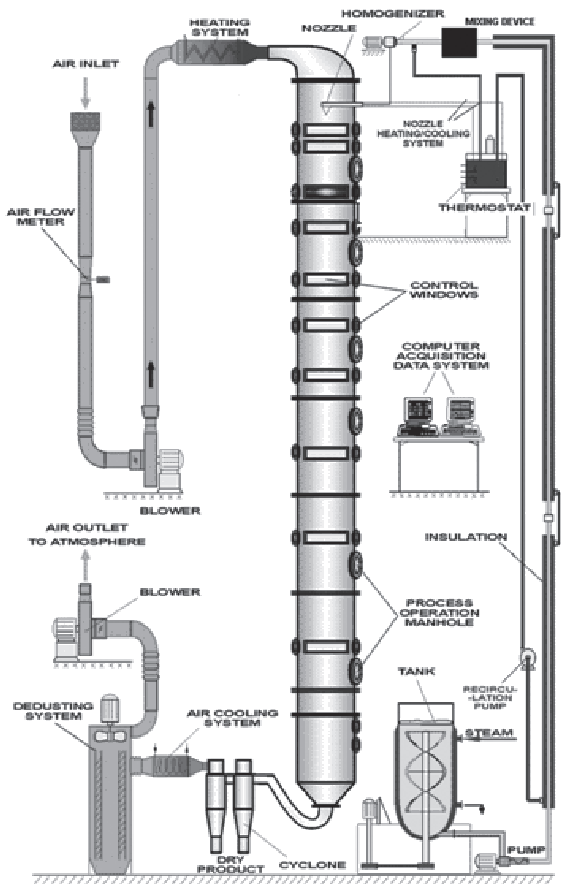


Fig. 1. Scheme of experimental equipment

To obtain foamed feed a precisely determined amount of inert gas (N_2) was injected to the feed at high pressure (Table 1) between the pump and atomizer. The gas and the feed were supplied to a mixing device to ensure good mixing and improved gas distribution in the liquid. Finally, the gas and the liquid were delivered to a mechanical homogenizer to produce fine gas bubbles in the liquid. Figure 2 shows a schematic of the feeding system applied in the gas-admixing method of foaming.

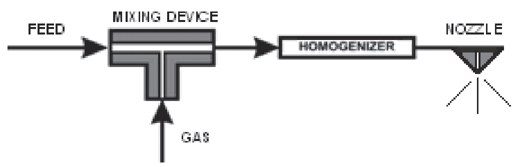


Fig. 2. Feeding system in gas-admixing method of foaming

Results and discussion

Tables 2 and 3 present final properties of maltodextrin and detergent powder. For each material six tests for different feed rates and foaming gas flow rates were performed (three for the feed rate equal to ~9 kg/h and three for ~14 kg/h).

Prosimy cytować jako: Inż. Ap. Chem. 2010, 49, 4, 62-63

Tab. 2. Final properties of maltodexrtrin powder (final moisture content 0.7-1.7%)

Test No	Feed rate [kg/h]	Foaming fast flow [g/h]	Arithmetic mean [µm]	*Sauter* mean [µm]	Bulk density [kg/m^3]	Tap density [kg/m^3]	Apparent density [kg/m^3]	Porosity [%]	Solubility [%]	Wettability [%]
1	9.1	0	79.1	79.1	266.8	411.3	779.2	65.78	97.6	1082
2	9	14.3	102.8	102.8	159.3	267.5	700	77.25	95.2	1535
3	9	40	148.2	148.2	180.6	276.6	629	71.33	93.9	935
4	14.9	0	94.8	94.8	320.7	477.2	810	60.41	98.8	453
5	14.5	21.5	146.1	146.1	204.8	334.5	617.8	66.89	94.9	677
6	14.7	75.05	168.8	168.8	178.9	310.3	577	68.61	97.3	1141

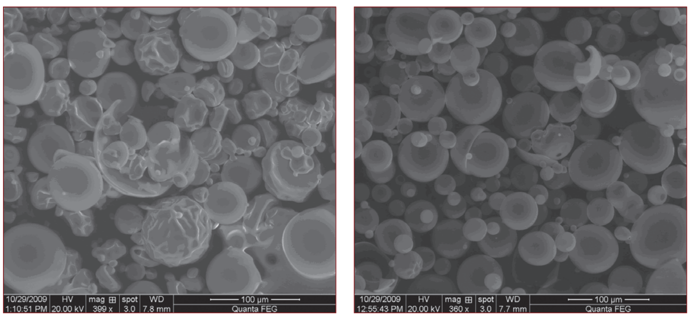
Tab. 3. Final properties of detergent (final moisture content 1.7-2.3 %)

Test No	Feed rate [kg/h]	Foaming fast flow [g/h]	Arithmetic mean [µm]	*Sauter* mean [µm]	Bulk density [kg/m^3]	Tap density [kg/m^3]	Apparent density [kg/m^3]	Porosity [%]	Solubility [%]	Wettability [%]
1	9	0	45	70.5	346	428.7	2074	83.3	98	1579
2	8.9	16	67.6	98.4	305.4	395.5	1978	84.6	94	795
3	8.9	42	81	126	236.4	311	2055	88.5	94	443
4	14.5	0	70.7	100.8	312.4	386.6	1978	84.2	94	729
5	14	22	84.8	123.1	185.4	233	1915	90.3	93	730
6	14	75	98.6	141.6	170.8	215.5	1986	91.4	92	556

Analysis of the results for maltodextrin drying shows that there is a clear trend of changes in analyzed products properties with increasing foaming gas flow rates. Bulk, tap and apparent density decreases, while *Sauter* mean diameter and porosity increase which is a result of the expansion of gas bubbles trapped in the droplets during foaming. Wettability of maltodextrin grows also with an increase of foaming gas flow which is due to bigger particle diameters caused by foaming. A foaming agent which was added to the raw material to make the foam more stable can also affect the wettability properties.

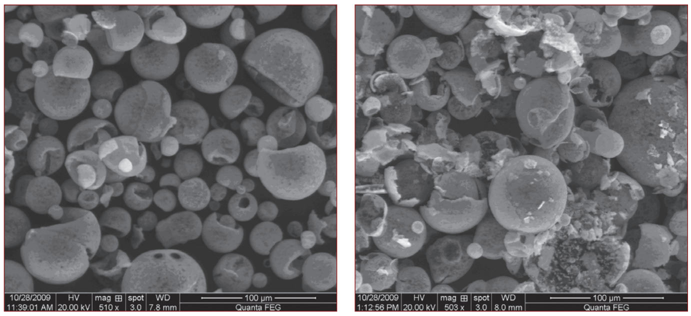
Analyzing wettability of the detergent, which is a porous material, we can observe an opposite effect. Materials with porous structure have high wettability because of capillarity forces which cause wetting of particles easier than in skin-forming material where skin of the particle surface must be dissolved first. Additionally, for porous material the expansion of gas bubbles trapped inside the droplets causes a burst of the droplets which decreases the average particle diameter and shortens the time of wetting.

A different effect of feed foaming on apparent density of the products was observed. For maltodextrin the apparent density is decreasing with higher foaming gas rates, which is the evidence of the presence of closed internal voids inside the particles as a result of foaming [7]. For the detergent this effect is less pronounced due to porous structure of the material.



Non-foamed Foamed

Fig. 3 Microscopic image of the powder (maltodextrin)



Non-foamed Foamed

Fig. 4 Microscopic image of the powder (detergent)

No significant effect of feed foaming on solubility of maltodextrin was observed, while lower solubility of the detergent could be explained by its chemical composition with sparingly soluble components in the formula.

Summarizing, we can conclude that in industrial conditions, feed foaming might be a powerful tool to control selected product properties. Figures 3 and 4 show examples of the microscopic images of foamed and non-foamed maltodextrin and detergent powders. A significant difference in the final product structure can be observed. Foamed particles of maltodextrin have a more uniform structure and circular shape, which has an effect on bulk and apparent density. More damaged particles are observed in the case of the detergent, which leads to e.g. worse wettability properties.

Conclusions

Extensive experiments on gas-admixing foam spray drying process were performed for skin-forming and porous materials.

Analysis of experimental results confirmed a strong effect of feed foaming on final product properties of both materials, e.g. an increase of *Sauter* mean diameter and porosity of the products, decrease of bulk and tap density at higher foaming gas rates. For skin-forming material apparent density is decreasing with higher gas flow rate, while apparent density of porous material is not affected by the foaming.

Wettability of detergent powder decreases at higher foaming rate, while an opposite effect is observed for maltodextrin which is a result of different structure of both materials. Experimental results prove that feed foaming in spray drying enables a control of selected physical product properties in industrial conditions.

REFERENCES

[1] *F. P. Hanrahan, B. H. Webb:* Food Engineering, 8, 36 (1961).

[2] *R. W. Bell, F. P. Hanrahan, B. H. Webb*: J. Dairy Sci., 46, 1352 (1963).

[3] *F. P. Hanrahan, A. Tamsma; K. K. Fox, M.Y. Pallansch*: J. Dairy Sci., 45, 27 (1962).

[4] *M. Kwapinska, I. Zbicinski*: Drying Technology, 23, 1653 (2005).

[5] *C.G. Greenwald, C. J King*: Journal of Food Process Engineering, 4, 171 (1981).

[6] *D. E. Walton, C. J. Mumford*: Transactions of the Institution of Chemical Engineers, 77 part A, 21 (1999).

[7] *I. Zbicinski, J. Rabaeva*: Drying Technology: An International Journal, **28**, nr 1, 103 (2010).

This work was carried out in the frame of research project no. R1401303 financed by the Ministry of Science and Higher Education (Poland).