

INFLUENCE OF STARCH TYPE AND METHOD OF BINDER INPUT ON GRANULATION QUALITY

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Abstract: The fluidized bed granulation had been investigated based on the experimental design and factorial analysis. The influence of process parameters (above all starch type and method of binder input) on the quality of product had been recognized and the optimal granulation parameters had been found. Four types of cold water soluble binders were used. The seven product quality characteristics such as an average diameter of granules, polydispersity index, flowability, slope angle, Carr index and residual moisture content were found. The optimal conditions were determined using factorial analysis. The results are useful in understanding the growth kinetics.

Keywords: granulation, fluidized bed, binders, factorial design, optimization

INTRODUCTION

Fluidized bed spray granulation is one of the most well-known technologies producing granules with good technological characteristics and permitting to combine some of technological stages in the one apparatus.

Fluidized bed spray granulation is used to produce coarse granular solid particles by spraying solutions or suspensions in the form of fine droplets on fluidized particles followed by drying in a stream of fluidizing air.

A form of granules and size distribution have a great influence on technological characteristics of tablet mass for direct compressing. It is necessary to have a number of optimal properties of tablet mass for transporting, storage, compressing process and for good characteristics of producing tablet (e.g. strength, gratefulness, disintegration et. al.). The most important properties of granules are good flowability (at least 5-6 g/s), high compressibility (70-100 N), optimal bulk density (more than 0.4-0.5 g/ml) and low natural slope angle (less than 40°).

A binder's input as solution for granulation is used frequently. Nowadays new method of binder's input is presented: the part of binder (as a powder) is loaded together with the granulated powders and the other one is sprayed as a solution.

The goal of present paper is to determine influence of binder's type, input method and process parameters on product quality and usability.

MATERIALS AND METHODS

Binders and granulated powder

Four types of water soluble binders were used: native maize starch (Mondamin) and three modified starches such as partially pregelatinized maize starch (Starch 1500, Colorcon®), pregelatinized maize starch (Lycatab® PGS, Roquette), hydrolyzed maize starch (Lycatab® DSH, Roquette).

Native maize starch is a traditional binder and is widely used at food industry.

Lycatab® PGS is a precooked starch resulting from the physical modification of native maize starch.

Starch 1500 has a mixture of properties of both native and pregelatinized starches. It performs the multiple functions of a binder, disintegrant, and flow-aid while having lubricant properties.

Lycatab® DSH is obtained through the controlled hydrolysis of native maize starch followed by spray drying. It combines the binding characteristics of starch with the advantage of fast and total solubility in water at room temperature.

Lactose powder (Lactochem, Domo) was used as initial material for granulation.

Fluid bed granulation

The scheme of fluidized bed granulation is presented on Fig. 1. Powders are fluidized and a binder solution is sprayed onto the fluidized particles, creating liquid bridges between particles. Its solidification by drying

results in agglomerates formation.

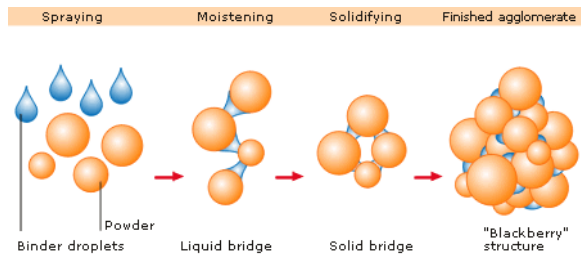


Fig. 1. The scheme of fluidized bed granulation process (Glatt GmbH, glatt.de)

As soon as the desired size of the agglomerates is achieved, spraying is stopped and the residual liquid is evaporated during drying in fluidized bed. The structures created by the liquid bridges are then maintained by solid binder bonds.

Fluidized bed equipment was Huettlin Mycrolab (Oyster Huettlin GmbH).

EXPERIMENTAL DESIGN

Definition of the functional dependences of all phenomena which have place during the liquid bridges formation and solidification in fluid-bed process is a complicated task. Application of the experimental design and factorial analysis allows to recognize the influence of process parameters on the quality of product and to find the optimal process condition.

The preliminary experimental work was carrying out to identify significant process parameters and to determine a range of variable parameters. Air flowrate, inlet air temperature, granulation time and drying time were determined as the main of process parameters influenced on product quality (factors X_i).

The temperature range was chosen based on binder's manufacture recommendations. The range of air flowrate was determined to good fluidization both for initial bed of lactose powder and for bed of granulated powder. The set of experiments allows to determine the ranges of granulation and drying times.

As it is mentioned above the type of binder and mode of it's input influence on product quality too. The maximum binder concentration in solution was 8 %. It was identified that solution of Lycatab DSH has the lowest viscosity and the most usability in a fluid bed spray granulation. Solutions of Lycatab PGS and of native maize starch were very viscous liquid for spraying. They were mixed with Lycatab DSH in following proportion: *Mixture of binders 1* – 37.5 % of Lycatab PGS and 62.5 % of Lycatab DSH; *Mixture of binders 2* – 50 % of native maize starch and 50 % of Lycatab DSH.

The complicated factorial design integrated with Latin square was used. Five factors (fluidized air flowrate, inlet air temperature, granulation time, drying time, mode of binder input) were graded on two levels and other one (type of binder) were graded on four levels. The factors and its grading are presented at Table 1. Mass of initial bed of lactose was 250 g. Quantities of binder was constant (10 % of lactose mass). The pump parameters were varied for each binder solution to have the constant granulation time (80 or 90 min).

RESULT AND DISCUSSION

Analytical investigation

The analytical investigations of products were carried out. The seven product quality characteristics such as an mean diameter of granules, polydispersity index, flowability, natural slope angle, form factor, Carr

Table 1. The factors (X_i) and its grading for granulation experiments

No	F (X1), m ³ /h	T (X2), °C	τ_{gr} (X3), min	τ_{dr} (X4), min	Mode of binder input (X5)		Binder type (X6)
					L _{sol} , %	L _{bed} , %	
1	25	50	90	15	100	-	Mixture of binders 1
2	20	50	90	15	50	50	Starch 1500
3	25	45	90	15	50	50	Lycatab DSH
4	20	45	90	15	100	-	Mixture of binders 2
5	25	50	80	15	100	-	Starch 1500
6	20	50	80	15	50	50	Mixture of binders 1
7	25	45	80	15	50	50	Mixture of binders 2
8	20	45	80	15	100	-	Lycatab DSH
9	25	50	90	8	100	-	Lycatab DSH
10	20	50	90	8	50	50	Mixture of binders 2
11	25	45	90	8	50	50	Mixture of binders 1
12	20	45	90	8	100	-	Starch 1500
13	25	50	80	8	100	-	Mixture of binders 2
14	20	50	80	8	50	50	Lycatab DSH
15	25	45	80	8	50	50	Starch 1500
16	20	45	80	8	100	-	Mixture of binders 1

index and residual moisture content were found (Table 2).

The products were investigated by optical microscopy and photos were digital processing. The weighted mean diameter (\bar{d}) of granules and polydispersity index (P.I.) were determined in the following way:

$$\bar{d} = \frac{\sum_{i=1}^k (n_i \cdot d_i)}{N}, \quad (1)$$

$$d_i = \sqrt{\frac{(d_k^{\min})^2 \cdot (d_k^{\max})^2}{d_k^{\min} \cdot d_k^{\max}}}, \quad (2)$$

$$P.I. = \sqrt{\frac{1}{k-1} \cdot \sum_{i=1}^k (d_i - \bar{d})^2}. \quad (3)$$

The Carr index (C.I.) shows the compressibility of a powder and could be determined in the following way:

$$C.I. = 100 \cdot \left(1 - \frac{\rho_B}{\rho_T}\right). \quad (4)$$

Table 2. Results of analytical investigations (quality criteria (Y_j))

No	C. I. (Y1), dimensionless	Flowability (Y2), g/s	Residual moisture content (Y3), %	Slope angle (Y4), °	Mean diameter, μm	P. I. (Y5), dimensionless
1	13.73	1.74	0.19	33.52	430	180.80
2	17.63	1.34	0.25	29.50	165	99.59
3	19.37	1.38	0.28	30.74	128	32.56
4	17.06	1.17	0.31	40.74	268	93.40
5	14.17	1.46	0.29	33.53	274	270.68
6	14.37	1.58	0.23	33.58	267	107.25
7	12.33	1.60	0.28	35.74	309	84.22
8	20.39	0.91	0.29	35.47	445	176.22
9	18.29	1.27	0.30	32.44	403	120.68
10	15.87	1.23	0.24	35.48	254	128.12
11	13.52	1.88	0.30	35.10	384	273.51
12	20.99	1.21	0.35	39.66	484	318.34
13	13.70	1.33	0.22	38.03	328	99.99
14	23.54	1.05	0.31	34.52	249	129.72
15	17.01	1.15	0.31	36.49	219	120.03
16	4.84	1.07	0.35	42.62	512	371.10

The granules size distribution for binder Starch 1500 case are presented in Fig. 2.

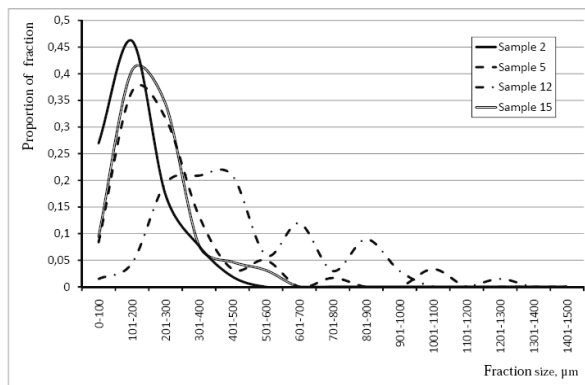


Fig. 2. Granules size distribution

It is obvious that input of all binder as a solution allows to make the bigger granules with broad

granules size distribution (see P.I. for experiments No 2, 5, 12 and 15 in Table 2).

To estimate of influence of all factors on product quality factorial analysis was carried out.

Factorial analysis

To determine the influence intensity of factors (X_i) on quality criteria (Y_j) the factorial analysis was carried out. At the first the dispersions of experiments repeatability were determined:

$$S_{Y1}^2 = 3.959, S_{Y2}^2 = 0.00069, S_{Y3}^2 = 0.00021, S_{Y4}^2 = 4.5, S_{Y5}^2 = 20.2.$$

The effect of factor was determined in the following way (Table 3):

$$m_i = \frac{1}{N} \left[\sum Y(X_i^{(+1)}) - \sum Y(X_i^{(-1)}) \right], \quad (5)$$

where $i = \overline{1,5}$.

$$m_6(l) = \frac{\sum Y(X_6^l)}{l}, \quad (6)$$

where $l = 4$.

The estimation of factors significance was carried out based on the Student's test for factors X1-X5 and the Duncan's test for the last one. Based on the result of factorial analysis the optimal conditions for each quality criteria were found (Table 3).

Table 3. Results of factorial analysis

Factors	Effect of factor					Optimal conditions for each criteria				
	Y1	Y2	Y3	Y4	Y5	Y1	Y2	Y3	Y4	Y5
X1	-0.786	0.141	-0.010	-0.999	-15.079	+1	+1	+1	+1	+1
X2	0.362	0.039	-0.028	-1.623	-20.784	-1	+1	+1	+1	+1
X3	1.007	0.067	-0.004	-0.800	-7.013	-1	+1	+1	+1	+1
X4	0.081	0.062	-0.016	-1.345	-32.298	-1	+1	+1	+1	+1
X5	0.654	0.066	-0.006	-1.554	-41.013	-1	+1	+1	+1	+1
X6	1	16.750	1.258	0.258	35.240	2	4	1	2	3
	2	13.273	1.320	0.295	35.075					
	3	17.108	1.375	0.270	35.503					
	4	17.073	1.390	0.303	35.973					

Because the optimal conditions for each criteria wasn't equal the neighboring point method was used.

Multiparameters optimization

At the first the effects of factors were normalized:

$$\bar{f}_j = \frac{f_j}{f_j^{opt}}, \quad (7)$$

where $j = \overline{1,16}$.

The coordinate vector of neighboring point was determined in following way:

$$F^{opt} = (\bar{f}_1^{opt}, \dots, \bar{f}_6^{opt}). \quad (8)$$

The distance from neighboring point was calculated in following way:

$$g_j = \sqrt{\sum_{i=1}^5 \left(\bar{f}_{j,i} - \bar{f}_{j,i}^{opt} \right)^2} \quad (9)$$

By analogy of eq. (5)-(6) the effects of factors on neighboring point (g) were estimated and the optimal conditions were found. There are: $F=25 \text{ m}^3/\text{h}$, $T=50 \text{ }^\circ\text{C}$, $\tau_{gr}=90 \text{ min}$, $\tau_{dr}=15 \text{ min}$, binder input is 50%/50%, type of binder is *Mixture of binder I*.

CONCLUSIONS

The investigation of fluid bed spray granulation was carried out to determine influence of binder's type and input mode on product quality and usability. The complicated factorial design integrated with Latin square was used. The analytical investigations of products were carried out. Based on factorial analysis and neighboring point method the optimal process parameters were determined.

NOMENCLATURE

F	air flowrate	m^3/h
T	air temperature	$^\circ\text{C}$
τ	time	min
L	part of total mass	%
\bar{d}	weighted mean diameter	μm
d_i	mean diameter of granule in i-fraction	μm
N	total amount	-
P.I.	polydispersity index	μm
C.I.	Carr index	-
ρ	density	kg/m^3
S^2	dispersions of experiments repeatability	
X	factor	-
Y	criteria	-
m	effect of factor	-
\bar{f}	normalized effect of factors	-
m	number of criteria	-
g	distance from neighboring point	-
Subscripts		
gr	granulation	
dr	drying	
sol	in solution	
bed	in bed	
B	freely settled powder	
T	tapped powder	

opt optimal

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