DRUG DEVELOPMENT AND INDUSTRIAL PHARMACY, 13(9-11), 1675-1701 (1987)



# EFFECT OF IMPELLER AND CHOPPER DESIGN ON GRANULATION IN A HIGH SPEED MIXER

P. Holm, Department of Pharmaceutics
Royal Danish School of Pharmacy
Universitetsparken 2, DK-2100 Copenhagen
Denmark

## ABSTRACT

Effects of impeller and chopper design upon granule growth are investigated by granulation of dicalcium phosphate in a Fielder PMAT 25 laboratory high speed mixer. It is shown that the effects of the impeller design with respect to the blade inclination and impeller rotation speed can be described in terms of the volume swept out by the impeller. A high swept volume causes high densification of the agglomerates and narrow granule size distributions. Chopper size and rotation speed have no effect upon the granule size distribution. It is suggested that the primary function of the chopper is to disturb the uniform flow pattern of the mass. Effects of deposition of moist mass on the wall of the bowl on granule growth are demonstrated, and suggestions for reducing the deposition are given.

## INTRODUCTION

In vertical high speed mixers, mixing, densification and agglomeration of wetted material are achieved due to shearing and compaction forces exerted by a three bladed impeller rotating in the horizontal plane at the bottom of the bowl. In addition the mixer is equipped with a chopper positioned at the wall of the bowl rotating at very high speed in order to cut lumps into smaller fragments during granulation.

Previous granulation experiments performed in a laboratory high speed mixer, Fielder® PMAT 25VG, have shown that granule growth is primarily affected by amount of liquid, impeller speed and processing time (1,2). It was found that the chopper had no comminuting effect on larger agglomerates, provided that the liquid distribution was homogenous. It was assumed that the chopper was ineffective due to its relative small size.

A recent comparison of granulation in various types and scales of high speed mixers has revealed that the differences in design of impeller and chopper affects granule growth and granule properties profoundly (3). The investigation emphasizes that only little attention has been paid to the design of the agitators, leading to difficulties in up-scaling, and transferring of results to other types of high speed mixers.

The aim of this study was to examine the effect of systematic changes in design of impeller and chopper on granulation in Fielder PMAT 25VG. The influence of impeller and chopper speed on granule growth, granule properties and flow pattern of the material were studied.

Dicalcium phosphate was chosen as model substance since this material was found to result in granules being very sensitive to variations in process conditions (1,2).

TABLE 1

Characteristics of the Starting Materials

| Materials | $\bar{d}_{gw}$ 1) µm | $s_{gw}$ 2) | Particle density 3) $g/cm^3$ |
|---|---|---|---|
| Dicalcium phosphate (quality 1) | 11 | 2,06 | 2,31 |
| Dicalcium phosphate (quality 2) | 14 | 2,20 | 2,39 |
| Corn starch | 15 | 1,30 | 1,51 |

1. Geometric mean weight diameter determined by microscopic counting technique.
2. Geometric standard deviation determined as the ratio of the 50% to the 15.9% size of the distribution.
3. Determined by a Ströhline Air Comparison Pycnometer.

## MATERIALS

Two different qualities of dicalcium phosphate (calcium hydrogen phosphate (Ph.Eur. grade, Albright & Wilson Ltd.) and a mixture of corn starch (Ph.Eur. grade, Maizena Industrieprodukte GmbH) and dicalcium phosphate were used. Characteristics of the materials are given in Table 1. The binder liquid used for granulation was a 15% w/w solution of PVP/PVA copolymer (Kollidon VA64, BASF) in destilled water.

## EQUIPMENT

A laboratory scale high speed mixer Fielder PMAT 25 VG) equipped with a cooling jacked was used for the granulation experiments. The design of impeller and chopper has been modified. Three different changeable impeller blades were constructed. The blade area was kept constant and the angle of inclination of the blades varied by levels of 30, 40 and 50 degrees. The standard impeller is similar to the impeller with blade angles of 30 degrees. The design of the changeable blade impeller is shown in Figure 1. Two choppers were constructed with a similar pair of knife blades, but different in length as shown in Figure 2. The length of the small chopper blades is 4.5 cm, equal to the standard chopper. The large chopper has a length of 9.5 cm. Compared with the standard chopper the blades are sharper in order to improve the comminuting effect.

## METHODS

Effects of the following apparatus and process variables were studied in $3 \times 2^3$ factorially designed experiments:

A. Impeller design at three levels of blade inclination (30, 40 and 50 degrees)

B. Chopper size (small, large)

C. Chopper rotation speed (1500 and 3000 rpm.)

D. Impeller rotation speed (200 and 400 rpm.)

The effects of factors A, B, C and D on granule growth were studied during wet massing. 8 kg of dicalcium phosphate (quality 1) was granulated with a constant amount of binder solution (1423 g) added by atomization with a flow rate of 200g/min and high impeller speed (400 rpm.) in order to assure a homogeneous liquid distribution. The liquid quantity was chosen so that granule growth primarily proceeded in the subsequent wet massing phase. During liquid addition the chopper was not in action. The cooling jacket was operating during the entire pro-

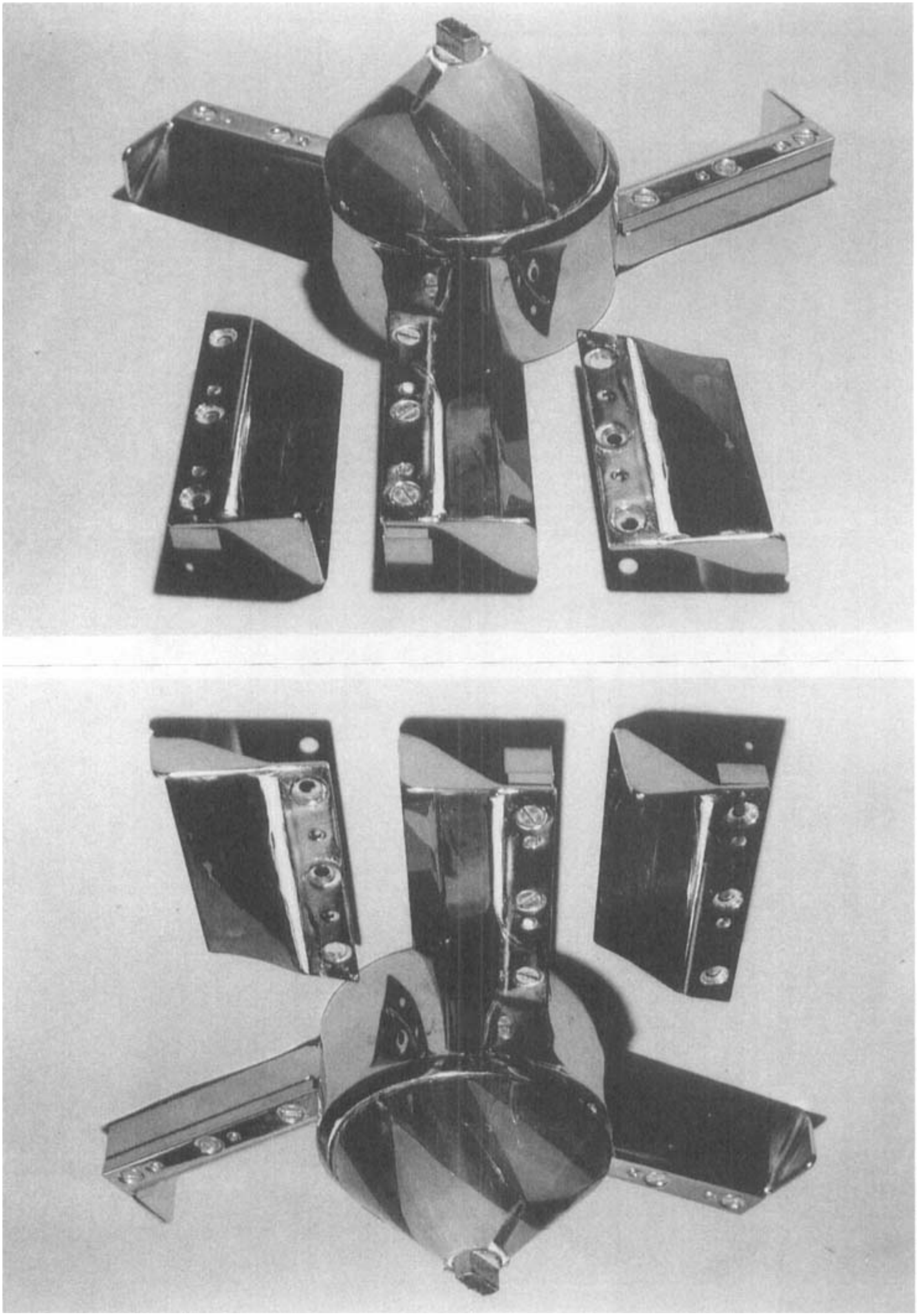

Figure 1

Design of changeable blade impeller

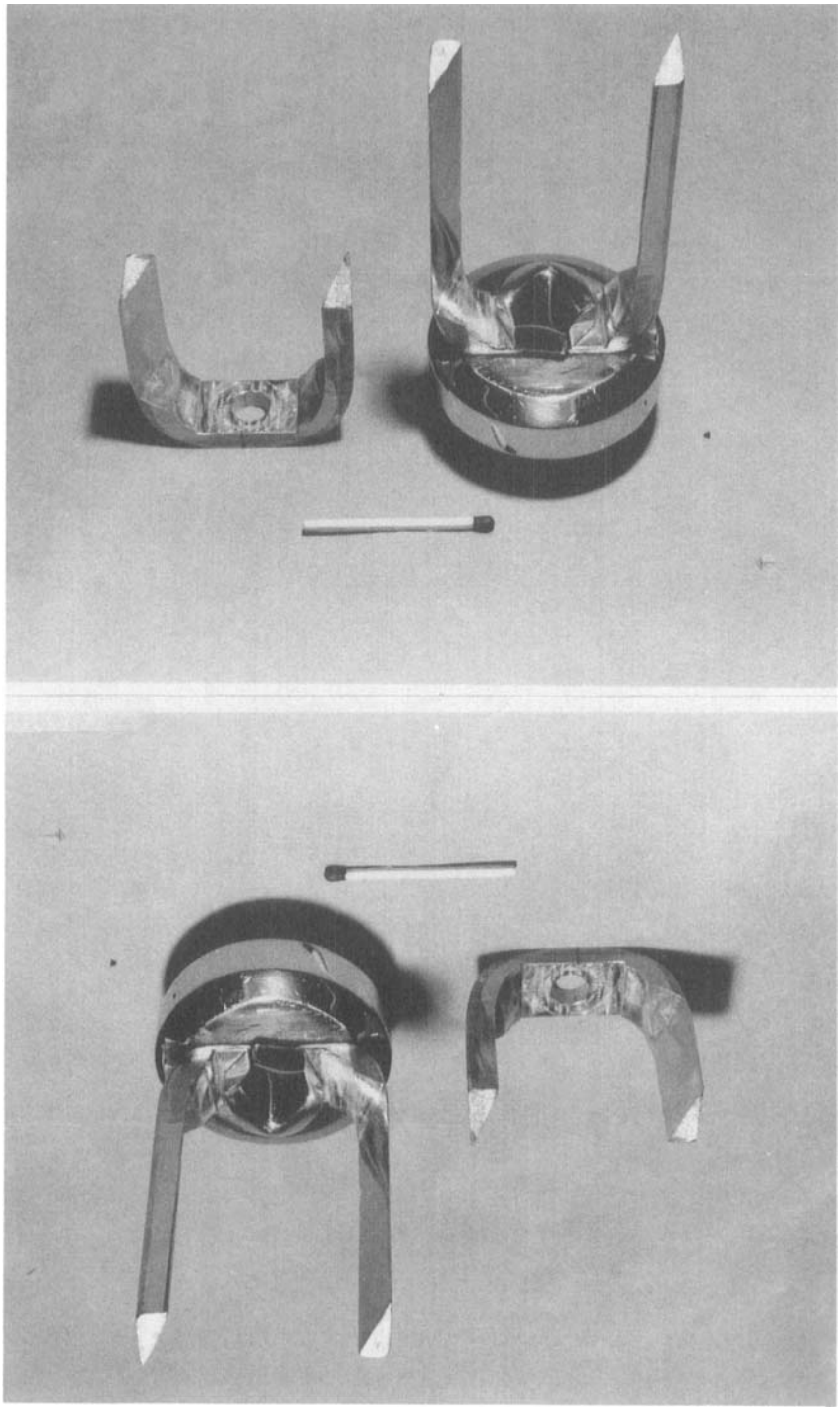

Figure 2

Design of choppers

cess in order to reduce the evaporation of moisture which in some experiments might be significant due to the temperature rise of the mass. The temperature of the mass was recorded during the process, as described previously (4). Samples of about 200 g were taken at the termination of the liquid addition and at wet massing times of 1, 3 and 6 min. The moisture content of the samples was determined by drying at room temperature. The granule size distribution was determined by sieve analysis of the tray dried samples (1) and characterized by the geometric mean weight diameter $\bar{d}_{gw}$ and the geometric standard deviation $s_{gw}$. The intragranular porosity was measured by a pycnometric method with mercury as penetraring liquid (5).

As deposition of the moistened mass on the wall of the bowl was significant in some experiments, the amount of material deposited was determined by measurement of the mass emtying freely after wet massing.

The flow pattern of the moist mass of dicalcium phosphate traced with a pink colour was studied during wet massing. With the lid in open position and a cylindrical shield on the top of the bowl the flow pattern could be examined visually and photographically from a vertical view.

Additional granulation experiments with dicalcium phosphate and a mixture of dicalcium phosphate and corn starch were carried out. The experimental details and results are given in the sections below concerning liquid distribution and effects of chopper on granule growth

## RESULTS AND DISCUSSION

### Effects of Impeller on Granule Growth

The data on granule size distributions obtained by the factorially designed experiments described above were submitted to analysis of variance. Significant effects on $\bar{d}_{gw}$ and $s_{gw}$ were found of factor A (impeller design) and factor D (impeller rotation speed). The effects of factors B (chopper design) and C (chopper rotation speed) were not significant.

Figure 3 shows the relation between $\bar{d}_{gw}$ and wet massing time. Since the chopper had no effect upon $\bar{d}_{gw}$, the plotted $\bar{d}_{gw}$'s are average values for experiments with the same impeller type and impeller rotation speed.

Figure 3 shows that $\bar{d}_{gw}$ in the liquid addition phase is influenced by the impeller type. The higher the impeller blade inclination was, the higher $\bar{d}_{gw}$ was found. The effect of impeller design was less pronounced after 6 minutes of wet massing. The effect of impeller rotation speed was highest for the 30 degrees blade, increasing growth rate at high level. However, the effect of rotation speed on $\bar{d}_{gw}$ levels out after 3 min. wet massing.

It has earlier been shown (6) that the effects of process conditions on $\bar{d}_{gw}$ can be interpreted on the basis of the effect of the liquid saturation upon $\bar{d}_{gw}$. Figure 4 shows the effect of liquid saturation upon $\bar{d}_{gw}$ for experiments with the impeller with 40 degrees blade inclination. The remaining data for the experiments with impellers with 30 and 50 degrees blade angles were in acceptable agreement with the correlation shown in Figure 4. The deviations from the drawn line were influenced by the deposition of moist mass deposited on the wall of the bowl, as discussed below.

The liquid saturation, S, is determined by the porosity, $\varepsilon$, and humidity, H, of the agglomerate by the equation (6).

$$S = \frac{H\ (1 - \varepsilon\ )\rho}{\varepsilon} \qquad (1)$$

where , $\rho$, is the particle density.

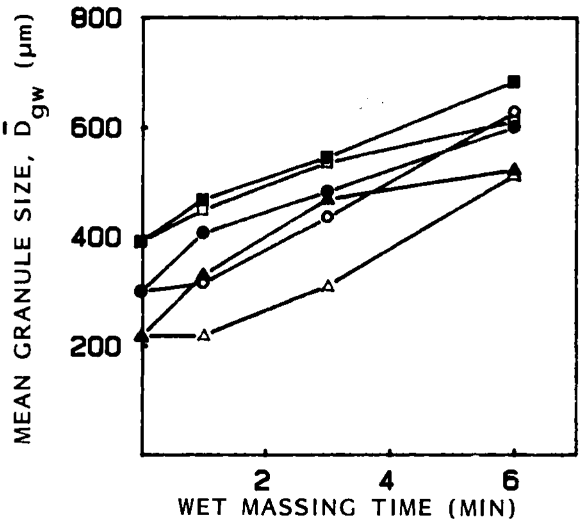


Figure 3

Effect of wet massing time on mean granule size. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 30 degrees (▲, △), 40 degrees (●, ○), 50 degrees (■, □). Impeller speed = 400rpm. (▲, ●, ■), 200rpm. (△, ○, □).

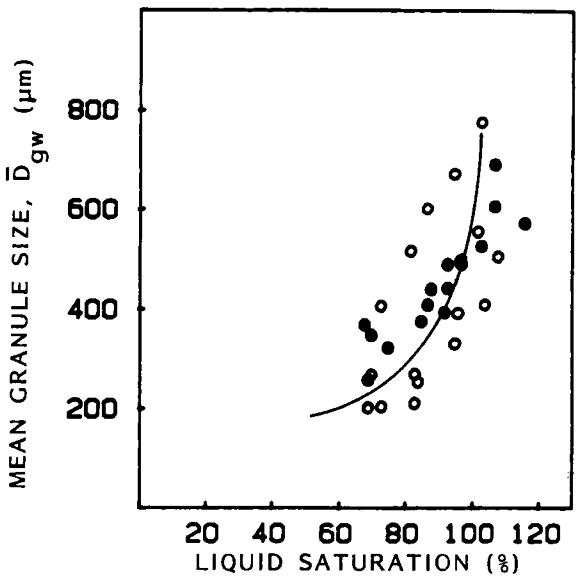


Figure 4

Effect of degree of liquid saturation on mean granule size during wet massing. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 40 degrees. Impeller speed = 200rpm. (○), 400rpm. (●).

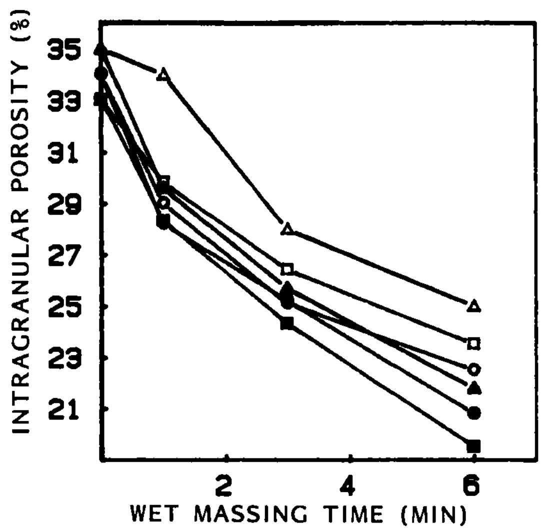


Figure 5

Effect of wet massing time on intragranular porosity. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 30 degrees (▲,△), 40 degrees (●,○), 50 degrees (■,□). Impeller speed = 400rpm. (▲,●,■), 200rpm. (△,○,□).

At constant moisture level, S is controlled by porosity. Therefore, coincident effects of process conditions upon $\bar{d}_{gw}$ and $\varepsilon$ are to be expected.

Analysis of variance applied to the granule porosity data obtained in the factorially designed experiment showed effect of impeller speed, only, with significance (P=0.999) after 6 minutes of wet massing. No effect of impeller blade inclination was found.

Figure 5 shows the relation between ε and wet massing time for average values of data obtained with same impeller type and impeller speed. Although the analysis of variance shows no effect of impeller blade angle on porosity, it appears that the lowest granule porosity was obtained at high impeller speed with the impeller blade angles of 40 and 50 degrees. The marked decrease in porosity at high impeller speed and high impeller blade angles showed an increased granule growth due to its increasing effect on liquid saturation cf. Eq. 1. However, Figure 3 demonstrates that the effect of impeller speed and impeller blade angles on granule size is not appreciable after 6 minutes of wet massing.

Table 2 gives the data on temperature increase and loss of moisture during wet massing at 6 minutes of wet massing. The greater temperature increase, the greater is the loss of moisture because of evaporation. Loss of moisture reduces S and consequently $\bar{d}_{gw}$ according to the correlation between S and $\bar{d}_{gw}$. Table 2 shows that the loss of moisture is greatest at high rotation speed with impellers having blade angles of 40 and 50 degrees. This means that the supposed effect of the impeller blade angle upon $\bar{d}_{gw}$ is counteracted by the evaporation of moisture.

Table 2 includes the relative swept volume, i.e. the volume swept out by the impeller blades per second divided by the volume of the bowl.

An examination of Table 2 shows that the relative swept volume is proportional to the temperature increase of the mass. According to previous studies (4) the increase in temperature is approximately proportional to the energy input by the impeller. Therefore, the relative swept volume is a measure of the energy input efficiency of the impeller. Table 2 shows that the relative swept volume is affected primarily by the impeller rotation speed and to a minor extent by the impeller blade inclination. Accordingly, the rotation speed has the major effect on the intragranular porosity cf. Figure 5. The effect of the blade inclination is minor.

The results demonstrate that the effects of impeller design with respect to blade inclination and impel-

TABLE 2

The effect of impeller blade angle and impeller rotation speed on loss of moisture, temperature increase of the mass and the relative volume swept out by the impeller at 6 minutes of wet massing. The results are the average values for experiments with same impeller speed and design.

| Impeller blade angle degrees | Impeller rotation speed rpm. | | |
|---|---|---|---|
| | loss of moisture % | temperature increase $^{o}C$ | rel. swept vol. $sec^{-1}$ |
| | 200 | | |
| 30 | 1.2 | 15.8 | 1.10 |
| 40 | 1.7 | 17.0 | 1.41 |
| 50 | 1.2 | 20.8 | 1.68 |
| | 400 | | |
| 30 | 1.7 | 24.8 | 2.20 |
| 40 | 2.2 | 31.3 | 2.82 |
| 50 | 3.2 | 38.0 | 3.36 |

ler rotation speed upon intragranular porosity and granule growth can be described on the basis of the relative swept volume or energy input efficiency of the impeller.

## Granule Size Distribution

The granule size distribution is characterized by the geometric standard deviation $s_{gw}$. Analysis of variance applied to $s_{gw}$ for the factorial experiments showed sig-

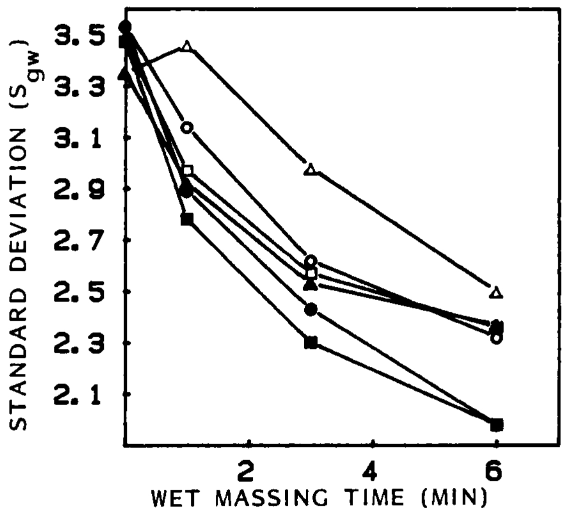


Figure 6

Effect of wet massing time on the geometric standard deviation of the granule size distributions. Starting material: Dicalcium phosphate (quality 1).
Impeller blade inclination = 30 degrees (▲, △), 40 degrees (●, ○), 50 degrees (■, □). Impeller speed = 400rpm. (▲, ●, ■), 200rpm. (△, ○, □).

nificance (P = 0.99) for the effect of impeller rotation speed at 1, 3 and 6 minutes of wet massing and significance (P = 0.95) for the effect of impeller blade angle after 6 minutes of wet massing. No effect of chopper size and speed was found.

Figure 6 shows the relation between average standard deviations and wet massing time for the experiments with the same impeller speed and impeller design. The most narrow granule size distributions are achieved at high values of relative swept volume corresponding to high impeller speed and high blade angles. The high energy input at these experimental conditions results in significant temperature increase and evaporation of moisture cf. Table 2. Though deviations were observed, the most narrow granule size distributions were correlated with high relative swept volume and high loss of moisture during wet massing. The differences in granule growth patterns are revealed comparing granule size distributions during wet massing at low level of energy input (Figure 7) with high energy input (Figure 8).

Figure 7 shows the changes in granule size distribution during wet massing at impeller blade angle of 30 degrees and low impeller rotation speed. Granule growth is initiated in the wet massing phase by disappearance of fines under 75 µm due to nucleation of primary particles. After about 3 minutes of massing mean granule size begins to increase, and after 6 minutes a wide size distribution ($s_{gw}$ = 2.76) with a large content of lumps over 4 mm is obtained.

In contrast, high energy input corresponding to impeller blade angle of 40 degrees and high impeller speed results in a narrow granule size distribution ($s_{gw}$ = 1.98) after 6 minutes of wet massing, as shown in Figure 8. Due to the high intensity of agitation, nucleation of primary particles less than 75 µm are initiated during liquid addition and roughly terminated after 1 minute of wet massing.

It is assumed that granule growth is initiated by nucleation of primary particles and proceeds by coalescence between nuclei and agglomerates.

Granule growth by coalescence requires a certain limiting strength and deformability of the agglomerates (7). The potential for growth by coalescence is repressed by increase of strength and decrease of plasticity of the agglomerates. Agglomerates of dicalcium phosphate require liquid saturation beyond 80 % to provide sufficient surface deformability for growth by coalescence (6). These

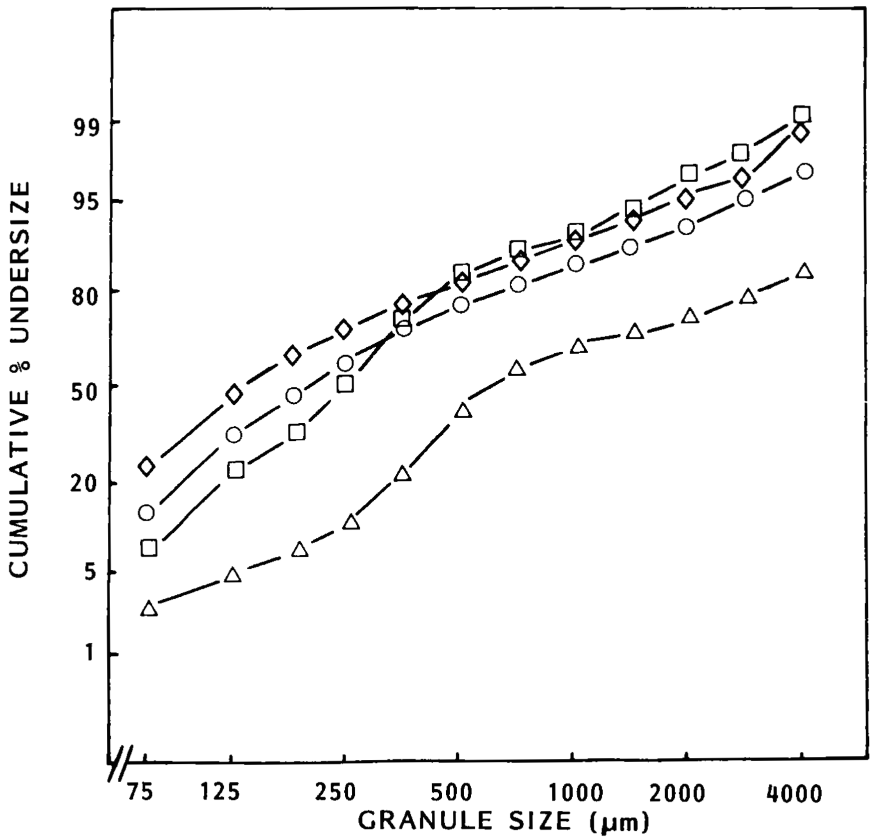


Figure 7

log-probability plot of cumulative weight distributions during wet massing. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 30 degrees. Impeller speed = 200rpm. Speed of large chopper = 3000rpm. Wet massing time = 0 min. (◇), 1 min. (○), 3 min. (□), 6 min. (△).

conditions are present after 3 min. or 1 min. of wet massing for the experiments shown in Figures 7 and 8 respectively. At further wet massing granule growth is delayed at high energy input (Figure 8) compared to granule growth at low energy input (Figure 7). It is sup-

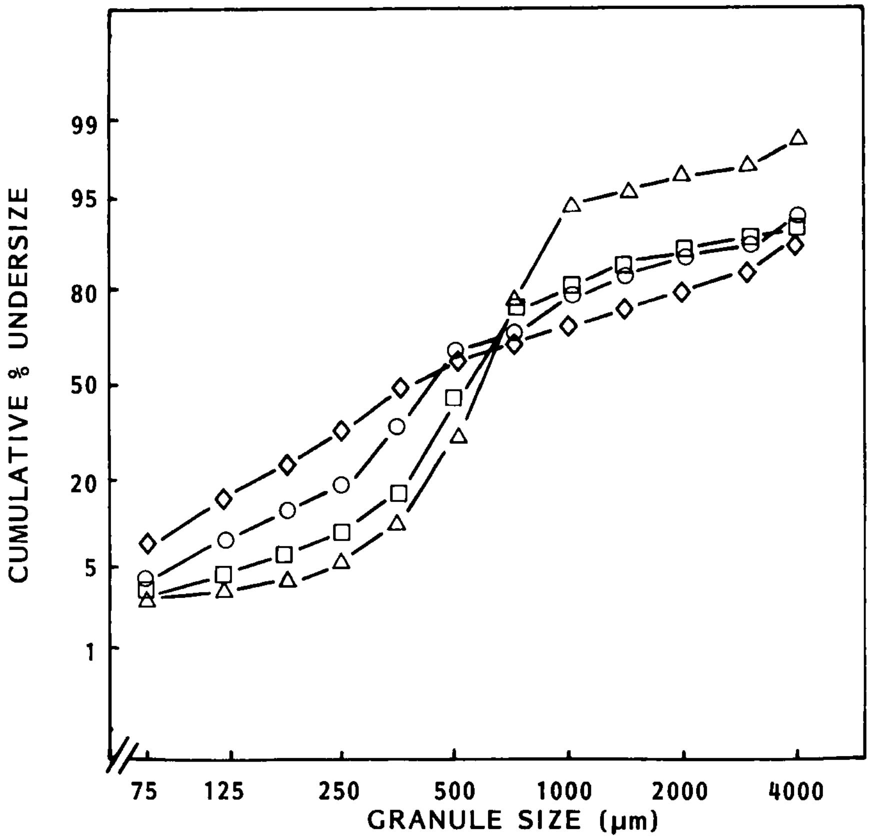


Figure 8

log-probability plot of cumulative weight distributions during wet massing. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 40 degrees. Impeller speed = 400rpm. Speed of large chopper = 3000rpm. Wet massing time = 0 min. (◇), 1 min. (○), 3 min. (□), 6 min. (△).

posed that the marked densification of granules and evaporation of surface free liquid at high energy input decreases the potential for growth by coalescence due to increased strength and reduced surface plasticity of the agglomerates. The intense agitation of the impeller might contribute to the narrowing of granule size distribution during wet massing by crushing of larger agglomerates (Figure 8). It is assumed that granule growth at low energy input proceeds by random coalescence between agglomerates without appreciable crushing of larger agglomerates, resulting in a wide granule size distribution.

## Liquid Distribution

It has previously been demonstrated that inhomogeneous liquid distribution might result in the formation of overwetted lumps (1,2). It was claimed that homogenous liquid distribution is achieved by atomization of the binder solution. However, the results of the experiments above revealed that the amount of deposited material on the wall of the bowl during liquid addition can affect the liquid distribution, too. The stationary material on the wall of the bowl is wetted to a minor extent during liquid addition resulting in overwetting of the material in agitation. The moisture content of samples taken out of the bowl after liquid addition confirmed that the average moisture content was higher (15.4%) than the theoretical moisture content (15.1%) calculated on basis of the liquid amount added. Visually, observations showed that significant amount of moist material might be deposited during liquid addition, and the amount of stationary material was increased in the subsequent massing phase, especially at low impeller speed. The amount of deposited material and an inhomogeneous liquid distribution must interfere with the effects of process variables on granule growth described above.

In order to reduce the amount of deposited material, the bowl was covered with polytetraflourethylene-tape (PTFE-film tape, Scotch 5490 3M). The factorial experiments above were partially repeated, with the use of impeller with blade angle of 40 degrees only. The quality of dicalcium phosphate used was the same as for the previous experiments.

The deposition of material was reduced markedly during the process. Without PTFE-tape on the wall of the bowl 50% of the mass was deposited after 6 minutes of wet massing, at high impeller speed, whereas PTFE-tape resulted in only 20% of deposited material in average of all experiments. The average moisture content of the mass after liquid addition (14.8%) agreed acceptably with the theoretical value (15.1%), and confirmed that the total mass has been wetted. The estimated moisture content must be slightly lower than the theoretical value due to evaporation of moisture during liquid addition.

In accordance with the results above, neither chopper rotation speed nor chopper size had effect on granule size distribution. Figure 9 shows comparisons between average content of lumps over 2 mm for experiments with same impeller type and rotation speed, performed with or without PTFE coated bowl. The content of lumps is very low at termination of liquid addition when the bowl is coated, due to the homogeneous liquid distribution. After 6 minutes of wet massing the amount of lumps is at the same level without PTFE coating, reflecting that the liquid is homogeneous distributed by agitation. The increase in amount of lumps after 3 minutes of wet massing at low impeller speed and coated bowl indicated that lumps are formed by agglomeration. The homogeneous liquid distribution achieved by PTFE-coated bowl resulted in a better reproducible granule size distribution at termination of wet massing. The reproducible granule properties obtained in the granulation experiments with coated bowl are reflected in the relation between $\bar{d}_{gw}$ and liquid saturations shown in Figure 10. The data fit the correlation within nar-

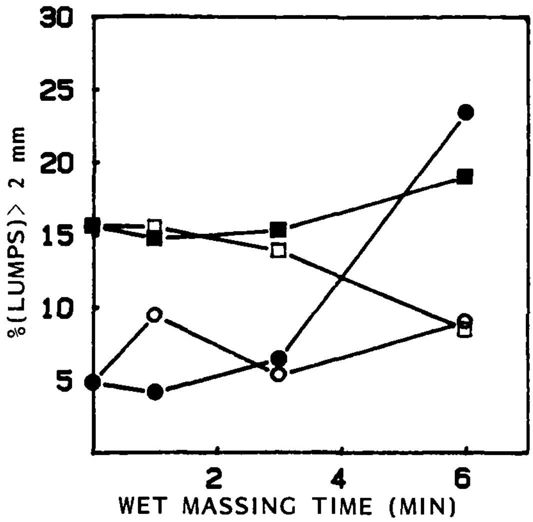


Figure 9

Effect of wet massing time on amount of lumps, larger than 2 mm. Starting material: Dicalcium phosphate (quality 1). Impeller blade inclination = 40 degrees. PTFE-coated bowl = (○, ●). No coating = (□, ■). Impeller speed = 200rpm. (●, ■), 400rpm. (○, □).

row limits compared to the deviation observed in the previous experiments cf. Figure 4.

It is concluded that reproducible granule growth patterns presuppose homogeneous liquid distribution, which is provided by atomization of the binder liquid and by reduction of amount of deposited material on the wall of the bowl.

Studies on the flow pattern of the moist material during wet massing showed that both impeller and chopper speed affect the amount of deposited material. The centrifugal forces applied to the mass by the impeller gives rise to the formation of a ring of fluidized material at the wall of the bowl. At high impeller speed and

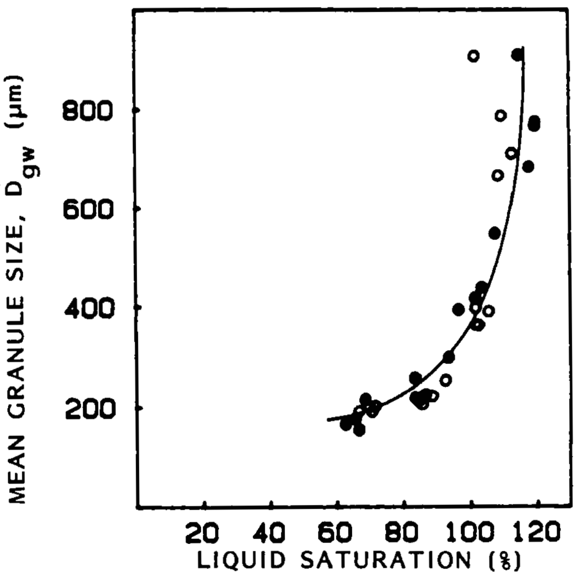


FIGURE 10

Effect of degree of liquid saturation on mean granule size during wet massing. Starting material: Dicalcium phosphate (quality 2). Impeller blade inclination = 40 degrees. PTFE-coated bowl. Impeller speed = 200rpm. ( ○ ), 400rpm. ( ● ).

high inclination of blade angles the material is lifted towards the top of the bowl. The intense agitation at high impeller speed prevents the deposition of stationary material on the wall of the bowl. At low impeller speed appreciable amount of moist material might be deposited even with PTFE-coated bowl. The chopper at high rotation speed prevents the deposition of material at its circumferences.

## Effects of Chopper on Granule Growth

In the granulation experiments above neither chopper size nor chopper speed had effect on granule size disstribution. Since larger agglomerates are not comminuted, it might be due to their high strength. In order to reduce the strength of the agglomerates corn starch was added to dicalcium phosphate. The effect of starch on granule strength is caused by the relatively narrow size distribution as well as the rounded particle shape preventing particle interlockings.

Factorial experiments were performed in a PTFE-coated bowl with the small as well as the larger chopper. Impeller blade angle was kept constantly at 40 degrees. Rotation speed levels were the same as in the previous experiments. A mixture of corn starch and dicalcium phosphate (quality 2) in the proportion of 45/55 wt./wt. % was used. The experiments were performed with 7.0 kg starting material and 2400 g binder solution added by a liquid flow rate of 200g/min.

The chopper had effect at high speed on the amount of lumps over 2 mm during wet massing, when the impeller speed was at low level. Figure 11 shows the amount of lumps during wet massing for the experiments with large chopper. The chopper size had no effect on the amount of lumps. At low impeller speed granule size rises slowly, and it is therefore likely that the chopper at high speed is effective enough to comminute the larger agglomerates which are formed.

Previous results on granulation of dicalcium phosphate (1,2) have shown that the standard chopper at high speed (3000 rpm.) had a slight reducing effect on the amount of lumps compared to experiments without chopper action. Studies of the flow pattern of the moist material showed that the chopper disturbs the uniform flow of material formed by action of the impeller. At high chopper speed material is wiped towards the center of the bowl and against the lid of the bowl, and the material flows in a more helixlike ring at the wall of

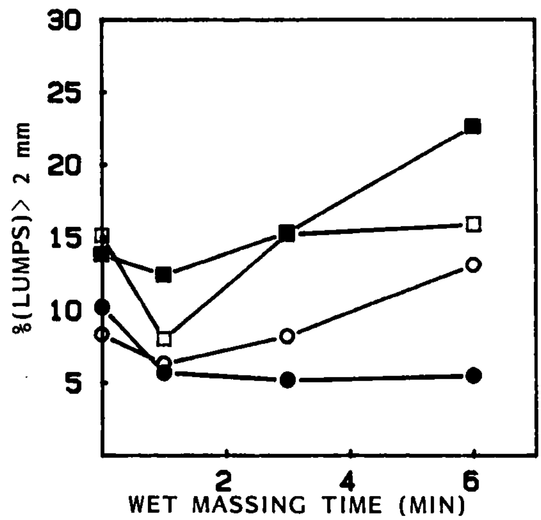


FIGURE 11

Correlation between amount of lumps larger than 2 mm and wet massing time. Starting material: Dicalcium phosphate (quality 2)/corn starch, 55/45 wt./wt.%. PTFE-coated bowl. Impeller blade inclination = 40 degrees. Large chopper. Impeller speed = 200rpm. (○, ●), 400rpm. (□, ■). Chopper speed = 3000rpm. (●, ■), 1500rpm. (○, □).

the bowl. Even when the chopper is out of rotation, material is wiped against the center of the bowl when passing the chopper.

Since the chopper might have an effect on granule growth when just mounted, additional experiments were carried out comparing granule growth with the large chopper at high rotation speed (3000 rpm.) with experiments without chopper mounted. The impeller with blade angle of 40 degrees was used at two levels of rotation speed (200, 400 rpm.). The bowl was coated with PTFE-tape. Dicalcium phosphate (quality 2) was

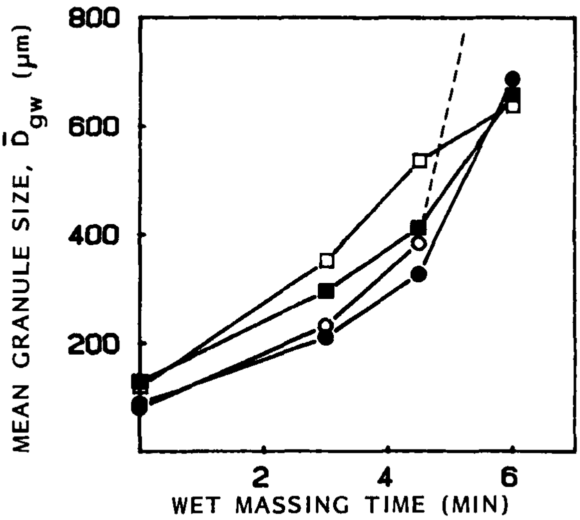


FIGURE 12

Correlation between mean granule size and wet massing time. Starting material: Dicalcium phosphate (quality 2). PTFE-coated bowl. Impeller blade inclination = 40 degrees. Large Chopper. Impeller speed = 400rpm. (○, ●), 200rpm. (□, ■). Chopper speed = 3000rpm. (●, □). Chopper not mounted (○, □).

used as starting material and the liquid amount was 1500 g at low impeller speed and 1375 g at high impeller speed in order to achieve comparable granule growth during wet massing at the two rotation levels. The remaining process conditions were similar to previous experiments with dicalcium phosphate. Figure 12 shows the relation between granule size and wet massing time at the different process conditions. The dotted line indicates that granule growth gets uncontrolled after 3 min. of wet massing when the chopper is not mounted. When the large chopper rotates at high speed, granule growth is more gradual. Figure 13 shows

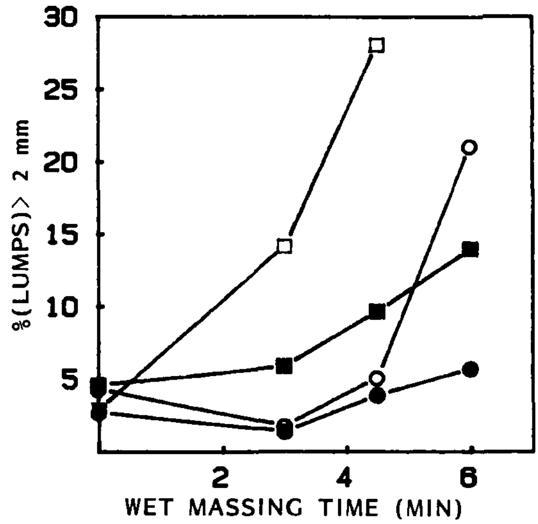


FIGURE 13

Correlation between amount of lumps larger than 2 mm and wet massing time. Starting material: Dicalcium phosphate (quality 2). PTFE-coated bowl. Impeller blade inclination = 40 degrees. Large Chopper. Impeller speed = 400rpm. (○, ●), 200rpm. (□, ■). Chopper speed = 3000rpm. (●, □). Chopper not mounted (○, □).

the amount of lumps over 2 mm during wet massing at the same experimental conditions. The amount of lumps is very high when the chopper is not mounted and the impeller speed is low. Though changes in chopper speed or size of the chopper as demonstrated above do not affect granule growth of dicalcium phosphate, the action of the chopper reduces the amount of lumps formed by agglomeration and thereby prevents that granule growth rate rises steeply within narrow limits of processing time.

## CONCLUSIONS

Granule growth of dicalcium phosphate is primarily affected by the energy input efficience of the impeller, which is shown to be satisfactory approached by the relative volume of material swept out by the impeller.

High energy input corresponds to high rotation speed of the impeller and high blade inclination. The results demonstrate that an increasing relative swept volume reduces the intragranular porosity. The high energy input is followed by an increasing mass temperature giving rise to increasing evaporation of moisture.

It is shown that a high energy input is associated with the formation of narrow granule size distributions. The effect can be explained by the evaporation of moisture, which reduces the surface liquid at the agglomerates and therefore reduces the rate of granule growth by coalescence, especially for the larger agglomerates.

It is notable that neither chopper size nor its rotation speed showed effects upon the size distribution of dicalcium phosphate granules. When the strength of the agglomerates was reduced by addition of corn starch, the chopper rotation speed had effect upon the amount of larger agglomerates due to a comminuting effect, whereas the size of the chopper had no significant effect.

Studies of the effect of the chopper, not in action, on the flow pattern of the moist material revealed that it affects the flow of material similar to the chopper in rotation. It might be therefore that no effect of chopper action on granule growth has been found in previous investigations (1,2). However, chopper speed can affect granule growth in other types of high speed mixers (3), presumeable due to a different flow pattern of the material.

It is assumed that the primary function of the chopper is to disturb the uniform flow pattern of the material formed by action of the impeller. Thus the design and speed of the chopper are of minor importance to its effect on granule growth.

It was discovered that the amount of deposited material on the wall of the bowl might influence the granule growth process. Deposition of material during liquid addition gives rise to inhomogeneous liquid distributions and difficulties in reproducing granule size.

Reduction in the amount of stationary material during liquid addition and wet massing is obtained by high agitation intensity of impeller and chopper or by PTFE-coating of the wall of the bowl.

## ACKNOWLEDGEMENTS

The experiments were supported by the Danish Council for Scientific and Industrial Research.

T.K. Fielder Ltd. is appreciated for delivering the modified impeller.

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