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Twin-screw granulation – a systematic analysis of process parameters

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ABSTRACT

Twin-screw granulation has a significant advantage over traditional granulation methods: the possibility of continuous manufacturing. Although this technology has drawn attention in the recent years, the general understanding of the process is limited. This study gives a brief overview of the most important process parameters and their influence on product quality. Hereby, experimental results from a benchtop granulator and an in-line particle size measurement have been analyzed. From this basic study conclusions can be drawn for how to tailor the particle size distribution in twin-screw granulation. The most crucial parameters are the liquid-to-solid ratio and the filling level of the screws.

INTRODUCTION

Twin-screw granulation has drawn attention in the recent years. Its possibility of continuous manufacturing allows the user to speed up research and development, be flexible on production, and produce in high and constant quality. A deep process understanding is the key to take the advantage of fast development. Therefore, this study summarizes the influence of the process parameters on the product quality with focus on the resulting particle size distribution.

MATERIALS AND METHODS

The granulation has been performed on the Thermo Scientific[TM] Pharma 11 Benchtop Twin-Screw Extruder. The machine has been converted using the "TSG-Kit" that includes longer screw shafts (L/D = 40 ¾). The granules have been analyzed in-line using the $Eyecon_2$ Particle Analyzer (Innopharma Technology, Dublin). Fig. 1 shows the setup that has been used for this study including the gravimetric Mini-Twin Feeder (Brabender Technologie, Duisburg) and a peristaltic pump for liquid feeding.

Figure 1. Setup for the benchtop twin-screw granulation

For the trials a placebo formulation of 62.8% lactose, 32% corn starch, 5% PVP 30 and 0.2% talcum has been granulated using water. The process parameters liquid-to-solid ratio (L/S), throughput, screw speed and barrel temperature as well as the screw configuration have been varied independently in this study. An overview of the experiments is given in Table 1. The throughput of the solid (at fixed liquid-to-solid ratio) has been varied between 0.5 and 3 kg/h in small steps to obtain a better resolution of the dependence. The screw configuration obtained 0 to 3 kneading zones with 3 30° forward kneading elements each.

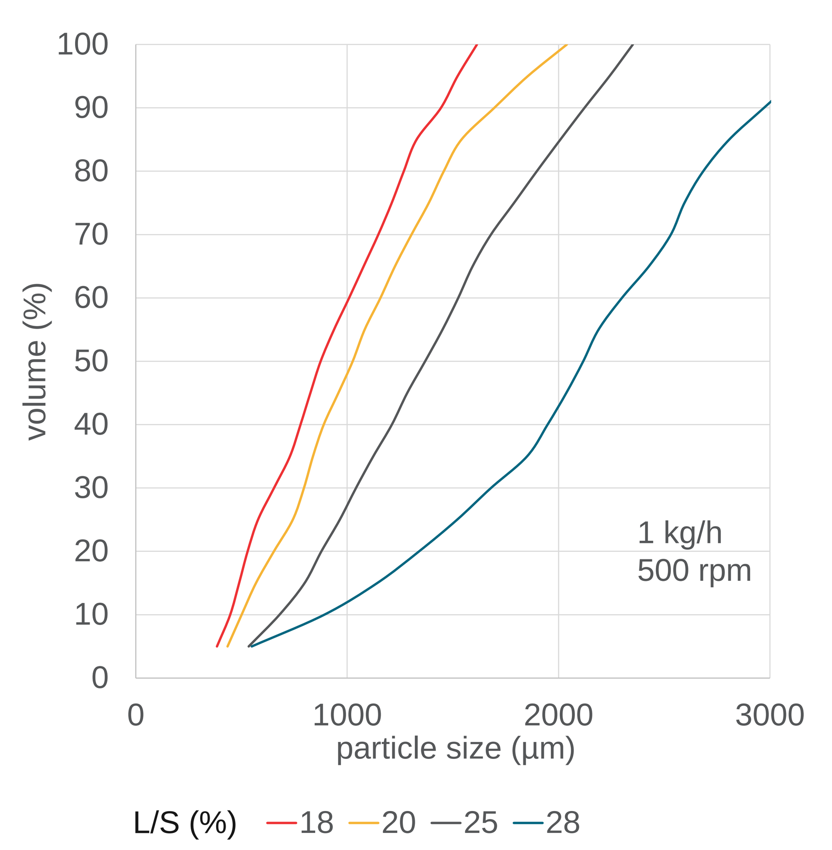
Table 1. Overview of the experimental design

Parameter	--	-	0	+	++
liquid-to-solid ratio (%)		18	**20**	25	28
throughput solid (kg/h)		0.5	**1**	3	
screw speed (rpm)		300	**500**	700	900
barrel temperature (°C)			**20**	30	40
screw configuration					
# of kneading zones (3 x F30)	0	1	**2**	3	
configuration name	sc0	sc1F30	**sc2F30**	sc3F30	

RESULTS

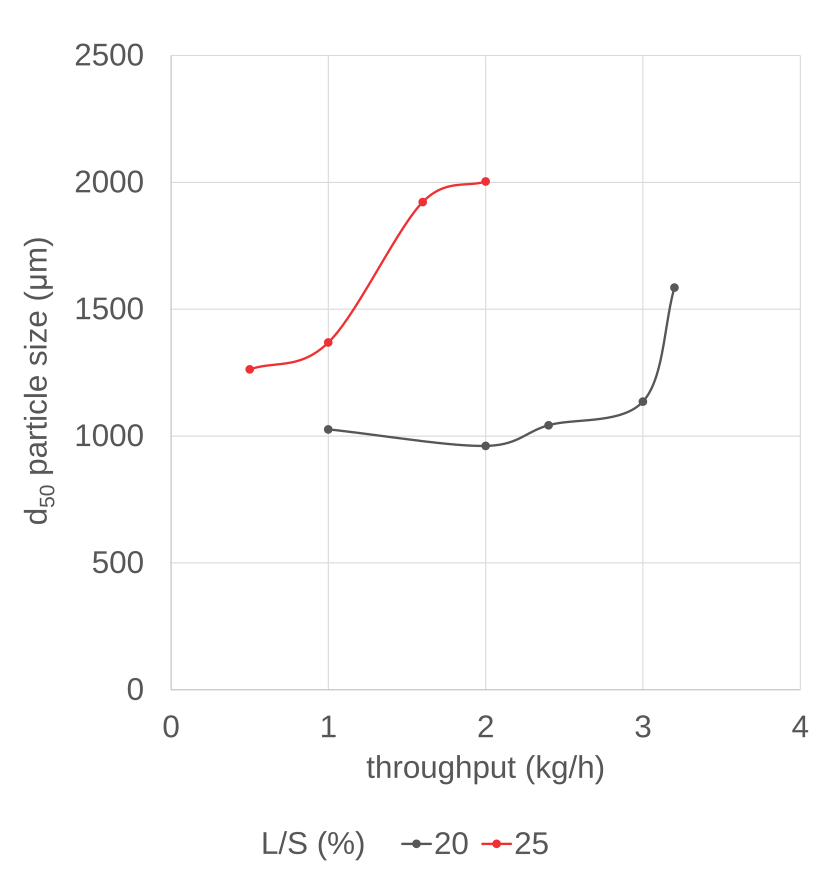
As published by several other authors, e.g. Thompson (2010), Keleb (2004) and Beer (2014), the liquid-to-solid ratio (L/S) has a significant influence on the granule quality. Fig. 2 shows the particle size distribution for varying L/S between 18% and 28%. The curve shifts to the right, thus, to higher particle size for rising L/S. Consequently, increasing L/S increases the mean mass diameter, the size and the amount of oversize particles and reduces the amount of fines

Figure 2. Particle size distribution for different liquid-to-solid ratios (L/S)



If the total throughput, i.e. the feeding rate of the solid and liquid, is increased the particle size distribution of the granules becomes wider, and the mean mass diameter (d_{50}) of the granules is bigger. The increase of mean mass diameter is shown in Fig. 3 for different L/S. For a lower value of L/S (20%) there is a wide range of throughputs that can be set without a big difference in the particle size. Only at the process boundary (above 3 kg/h) a sharp increase of the particle size is obtained. For a higher L/S of 25% this raise is reached between 1 kg/h and 1.5 kg/h following an S-shaped curve.

Figure 3. Mean mass diameter (d_{50}) for different throughputs of the solid feed at different liquid-to-solid ratios (L/S)



A similar effect can be obtained for increasing the barrel temperature (data not shown here). The higher the barrel temperature, the larger the granules and the larger the oversized granules. The effect on the particle size distribution width and the amount of fines is negligible.

If the screw speed is increased, a narrower particle size distribution can be reached and the d_{50} is smaller. This results in a decrease of oversize particles whereas the amount and size of fines stays more or less the same (see Fig. 4)

Figure 4. Particle size distribution for different screw speeds

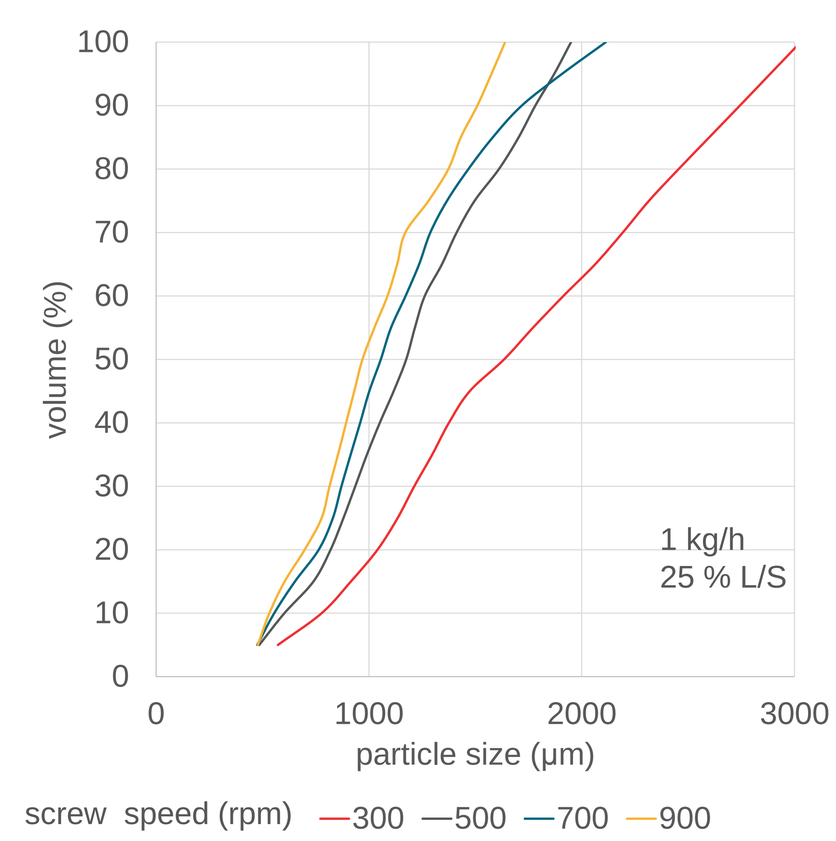
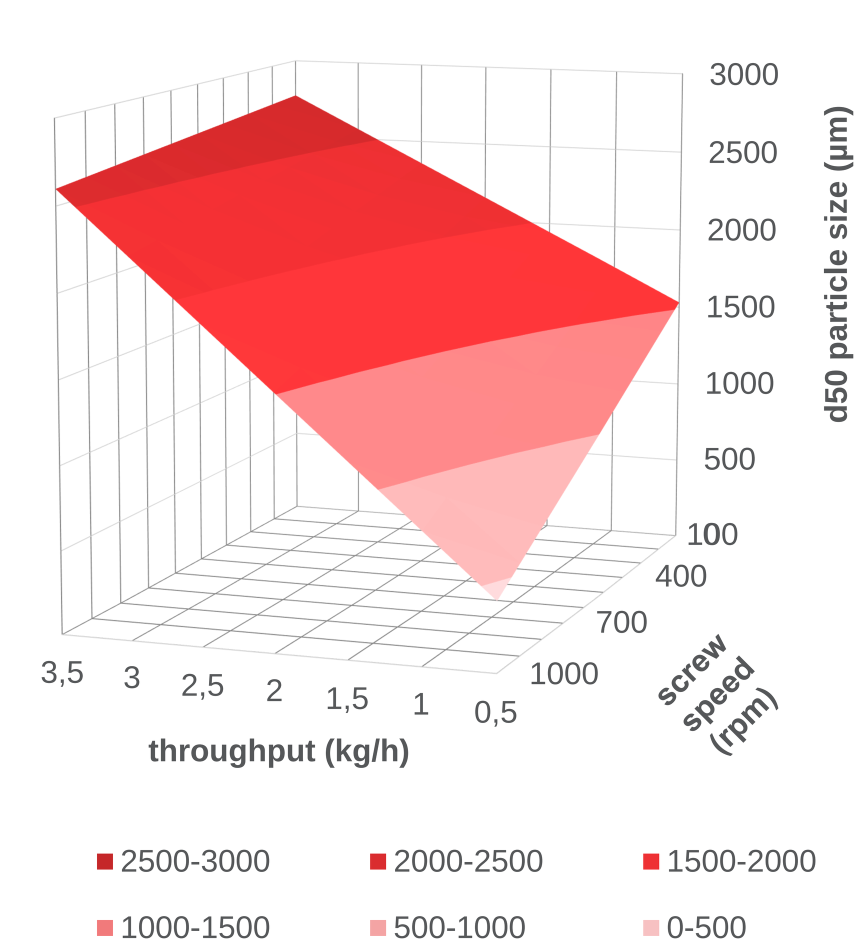


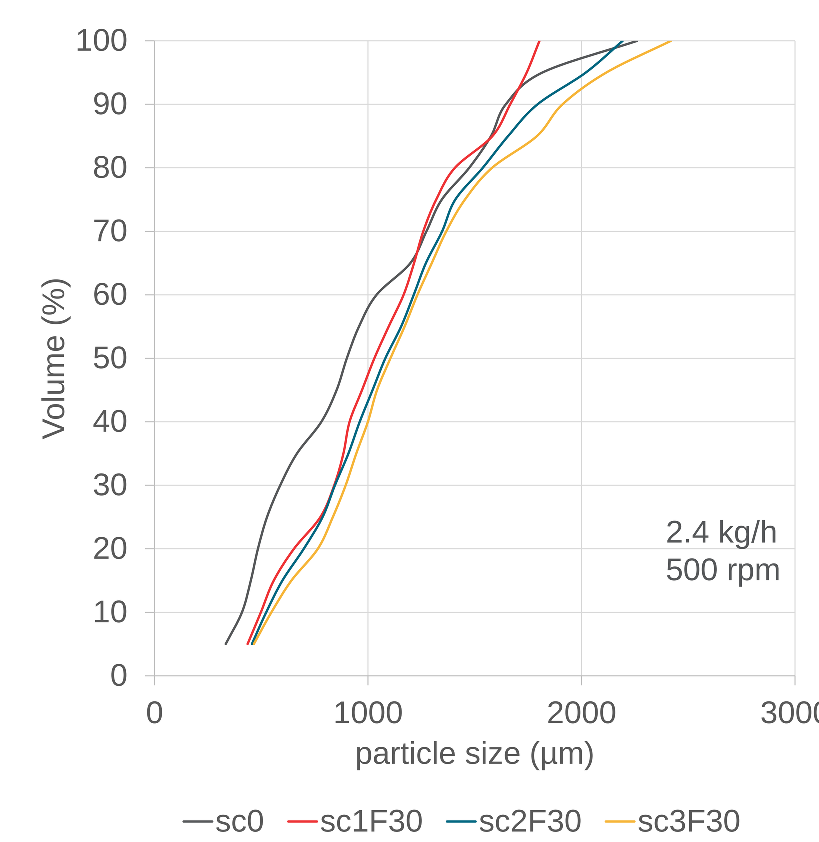
Fig. 5 summarizes the effect of throughput and screw speed on the mean mass diameter of the granules (d_{50}). Both, parameters change the filling level of the screws significantly. If the screws are filled with more material (larger throughput and lower screw speed), the material is compressed more which results in larger particles. If the screws are comparatively empty (high screw speeds and low throughputs), there is only a little compression and the granules are smaller.

Figure 5. Surface plot of the mean mass diameter over throughput and screw speed



Changing the screw configuration to more kneading zones results in a slight increase of particle size (see Fig. 6). More kneading zones lead to a higher filling level and thus to larger granules. These results are in good agreement with Djuric (2008) and Thompson (2010). However, for the formulation and the screw configurations tested in the present study, only a small dependence on the screw configuration can be observed.

Figure 6. Particle size distribution for different screw configurations



CONCLUSIONS

The liquid-to-solid ratio and the filling level of the screws are the most crucial parameters for twin-screw granulation. The latter is highly influenced by the throughput of the material through the granulator, the screw speed and the screw configuration. Based on this general data, the particle size distribution in a twin-screw granulation process can be easily tailored.

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