Utilising modelling approaches for the scale up of spray dryers

Hassan Abdullahi [1], Christopher L. Burcham, [2] Thomas Vetter [1]*

[1] School of Chemical Engineering and Analytical Science, University of Manchester, Manchester, UK
[2] Eli Lilly & Company, Indianapolis, USA

Spray drying is used to form particles from droplets (clear liquid or a suspension of particles) in a hot gas stream. There is recent and renewed interest in this technology within the pharmaceutical industry as it presents a way to co-formulate active pharmaceutical (APIs) with excipients [1]. By manipulating drying conditions (gas temperature, relative humidity, ratio of gas flow rate to liquid/suspension flow rate) spray drying also allows tuning the external shape, apparent density, etc. of the particulate product [1][5]. However, reproducing properties of a dried solid at a different scale presents numerous challenges and requires well-considered scale up methodologies [4].

For a long time, scale-up requirements have been based on experience and rule of thumbs, however such methods are not always reliable and can lead to unsuccessful scale-up operations. As such, better tools are required to minimise uncertainties [3]. To accomplish this, models that link drying conditions with the particle morphology obtained on the basis of a single droplet can be combined with droplet and gas flow trajectories obtained, e.g., from computational fluid dynamics [4]. This represents a platform for process scale up, as it links the process with product quality and component performance. By developing a clear picture of the effect of process variables on powder properties and through mathematical modelling, it is possible to identify key variables that will affect process drying behaviour and powder quality and hence achieve similar product quality on different scale. In the end, the drying behaviour and powder quality (for example, size distribution and moisture content) determines the residence time and hence, scale of a spray dryer [2][3].

In this work, we combine an extensive experimental and mechanistic modelling methodology to predict the drying behaviour and final particle size of single droplets. We utilise an acoustic levitator approach to mimic drying conditions in a typical spray dryer. We further develop a mathematical framework by solving conservation equations to describe the evolution of the continuous and discrete phases, in addition to equations describing external mass and energy transport. The solution to the conservation equations yield critical particle properties such as shell formation time, particle size and moisture content required to meet scale up demands. Finally, we elucidate on important properties that must be considered during scaling-up operations and others that need less stringent control.

References

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