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Review

Influence of particle properties on powder bulk behaviour and processability

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ABSTRACT

Understanding interparticle interactions in powder systems is crucial to pharmaceutical powder processing. Nevertheless, there remains a great challenge in identifying the key factors affecting interparticle interactions. Factors affecting interparticle interactions can be classified in three different broad categories: powder properties, environmental conditions, and powder processing methods and parameters. Although, each of these three categories listed is known to affect interparticle interactions, the challenge remains in developing a mechanistic understanding on how combination of these three categories affect interparticle interactions. This review focuses on the recent advances on understanding the effect of powder properties, particularly particle properties, its effect on interparticle interactions and ultimately on powder bulk behaviour. Furthermore, this review also highlights how particle properties are affected by the particle processing route and parameters. Recent advances in developing a particle processing route to prepare particles with desired properties allowing desired interparticle interaction to deliver favoured powder bulk behaviour are also discussed. Perspectives for the development of potential particle processing approaches to control interparticle interaction are presented.

Contents

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1. Introduction

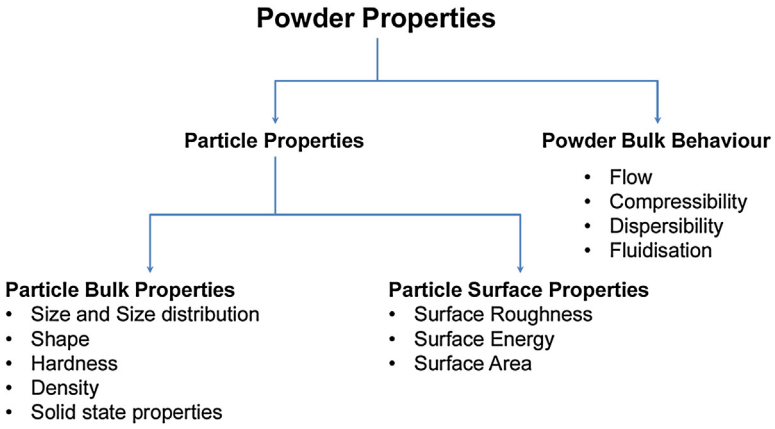
Powder handling and processing operations are dependent on the physicochemical properties of powder materials. Understanding these physicochemical properties of pharmaceutical powder can aid the development strategies for efficient and cost effective powder processing (Hou and Sun, 2008). Thus, the role of these properties of particulate pharmaceutical materials on cohesion and adhesion and their effect on powder flow has attracted much research interest over the past four decades (Feng et al., 2007; Ghoroi et al., 2013a; Kaerger et al., 2004; Lam and Nakagawa, 1994; Podczeck and Mia, 1996; Podczeck and Révész, 1993; Ridgway and Morland, 1977). Powder cohesion or adhesion is reported to be dependent on both the intrinsic material properties (surface functional end groups, surface energy, elastic modulus and plasticity) (Castellanos, 2005; Fichtner et al., 2008) and particle attributes (particle size, size distributions, shape and surface roughness) (Kaerger et al., 2004; Kumar et al., 2013; Lam and Newton, 1992; Podczeck and Mia, 1996; Rasenack and Müller, 2002).

On the other hand, the particle properties are known to be affected by the processing routes and processing conditions used for generating particles (Buckton, 2000, 1995; Heng et al., 2006; Planinšek et al., 2010; Smith et al., 2000). Milling can cause particulate breakage resulting in surface defects as well as surfaces with a heterogeneous surface energy landscape and irregular particle shape, which affects interparticle interaction (Williams, 2015). Similarly, in crystallisation, choice of solvent can result in different particle size, shape and crystal habit (Bourne and Davey, 1976), which can ultimately affect interparticle interactions and thereby the flow properties.

This review focuses on establishing linkages between particle processing approaches, processing parameters and particulate bulk behaviour. Recent advances towards developing a rational understanding of the role of particle properties on powder bulk behaviour is discussed with an emphasis on reviewing the effects of particle bulk and surface properties on powder flowability and compressibility. Finally the review also highlights opportunities to employ the understanding of the role of particle processing methods on particle properties to control powder bulk behaviour.

This review commences by providing an insight into different interparticle interaction mechanisms and recent modelling approaches relevant for the prediction of interparticle interactions. This is followed by discussion on modelling approaches, recent efforts on developing mechanistic understanding on the role of particle properties, *e.g.* particle bulk properties (solid state properties, particle size, shape, surface area), and surface properties (surface roughness, and surface energetics) on bulk powder behaviour, *i.e.* powder flowability, compressibility, are discussed in detail. Particle properties (both surface and bulk) are known to be affected by particle processing methods and routes, and a review of the role of particle processing methods (*i.e.* crystallisation, spray drying, milling, blending) and processing parameters (*i.e.* processing temperature, humidity, milling intensity, crystallisation solvents, *etc.*) is reported. Finally, this review focuses on recent and innovative efforts to combine the understanding on the effect of particle processing on particle properties, and the effect of particle properties on powder flowability and compressibility to tailor particles with desired powder bulk behaviour.

Measurement techniques and approaches have been covered previously in the literature, which includes reviews and books focusing on surface and bulk characterisation of particle properties (Buckton and Gill, 2007; Crowder et al., 2003; Gamble et al., 2012; Schulze, 2008; Svarovsky, 1987). Considering the availability of the literature on particle, surface and bulk characterisation techniques, this review does not intend to discuss material characterisation in detail. Interested readers can refer the individual reference for such information.



Scheme 1. Classification of powder properties used for the review.