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Air-suspension particle coating in the food industry: Part I — state of the art

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Abstract

Air-suspension particle coating has been slow to develop in the food industry. This is not surprising considering the economic constraints for low cost ingredients and low cost processing. Therefore, a need exists to adapt the process and formulation knowledge developed in the high-value pharmaceutical and health care industries to higher volume, low-cost production in the food industry. This paper reviews the current state of the art of air suspension coating as applied to the food industry. Of the few current applications, most have been developed by statistical experimentation which belies an understanding at the interface between food science and process engineering. This review concludes that a phenomenological approach is necessary in order to advance knowledge and accelerate product development. Such an approach will yield results independent of both the substrate powder and the coating device, which can be applied widely to select suitable coating materials and methods of application. A following paper will then elucidate key micro-level phenomena and discuss their implications.

Keywords: Review; Spray coating; Fluid bed; Granulation; Agglomeration; Food

1. Introduction

Air-suspension particle coating is a process where thin coatings are applied to powder particles. It is different to spray drying encapsulation, which produces particles consisting of a homogeneously blended matrix of the polymer entrapping the particle [1]. In contrast, air-suspension particle coating layers a clearly defined film coating over an existing core. To date, these have been on larger sized particles than produced in spray drying. Air-suspension coating processes are typically batch, where powder particles are recycled through the spray zone until the desired coating thickness is achieved. This makes it time consuming and expensive, but permits a number of successive coatings of different materials useful for controlled release applications. Air-suspension particle coating is established in the pharmaceutical and cosmetic industries, which are able to compensate for the cost of the process by the high price of their final product [2]. As a result, the overwhelming majority of the literature on air-suspension particle coating resides in the pharmaceutical literature.

The food industry is aware of the potential of particle coating technology and has identified numerous potential applications for its use. These include separation of ingredients from their environment (water, acid, oxygen, other food ingredients), which may be detrimental to the uncoated material or the food itself; stabilisation of the ingredient during processing (heat, pressure, moisture); to impart controlled release (during processing, storage or consumption); changing the physical characteristics of the original material by reducing the hygroscopicity, improving the flowability and compression properties, reducing dustiness or modifying density [3,4]. However, air-suspension particle coating has been slow to develop in the food industry [5]. Only limited, and application-specific, information regarding specific fluid bed processing techniques, including optimum processing conditions is available in the literature [3]. This slow development is not surprising given the economic constraints for low cost ingredients and low cost, high volume processing where every cent of additional cost per kilogram of product is important [4]. It is clear that air-suspension particle coating offers great opportunities in terms of product protection and

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control, but the difficulty is applying it within the economic constraints of the industry.

This review determines the current state of the art of air-suspension particle coating technology, with particular emphasis on the food industry. Coating technology, and its principles, applications and objectives are introduced. The selection of coating materials, the equipment, key process variables and coating quality are all addressed. 'Gaps' in the literature are identified and recommendations are made on how to advance the current knowledge of air-suspension particle coating.

2. Operating principle

The basic principle of both air-suspension particle coating and air-suspension agglomeration is to atomise a fine liquid spray into a bed of fluidised particles. The spray consists of a solute which acts as a coating medium, and a solvent in which the solute is dissolved or slurried. The liquid impinges and spreads on the particles. The fluidisation air evaporates the solvent, leaving a layer of solute on the surface of the particle. Particle growth can occur by either inter-particle agglomeration or surface layering (Fig. 1). Agglomeration occurs when liquid bridges form between colliding particles that are strong enough to prevent rebound. This study concentrates on surface layering which is enhanced by solvent lean conditions with intense fluidisation. These conditions prevent particles from agglomerating [6].

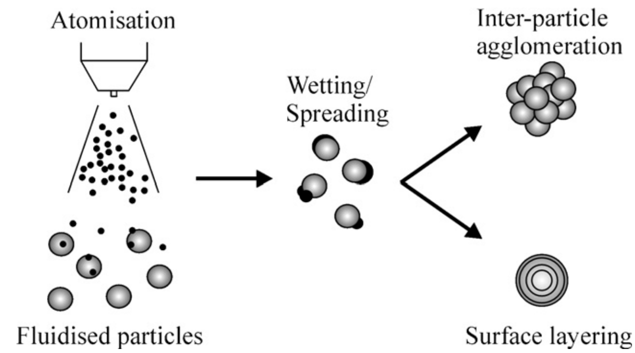

Fig. 1. Two particle growth mechanisms (inter-particle agglomeration and surface layering) in an air-suspension particle operation (adapted from [6]).

3. Coating objectives

Turton et al. [7] stated that the ultimate objective of a coating process is to produce individual particles, each with a well-controlled, even coating. They also discussed product quality where the 'quality' refers to both the standard achieved and its repeatability for properties or specifications of the finished product, e.g., loading of the active ingredient, dissolution characteristics, appearance, and shelf-life. Quality can be measured on a macroscopic level (coater performance) or a microscopic level (coating quality). At the macroscopic level Maa et al. [8] evaluated coater performance based on three criteria: product quality, product yield and production time, while Teunou and Poncelet [2] used four related but different criteria: material efficiency, energy efficiency, quality efficiency and productivity efficiency. Inevitably, there is a trade-off between these performance indicators, because high yield, low production cost and short production times are only ideal optimums. The actual optimum will vary based on the product and its application. For example, the adoption by commodity food industries of air-suspension coating technology will necessitate high product throughputs in the order of 2–20 tonnes of dry powder per hour. This is likely to compromise some aspects of quality.

4. Coating materials

The solvent in the coating solution is merely a vehicle to transport the coating material to the substrate surface and can be either aqueous or an organic liquid. Most food processes are limited to an aqueous carrier because of stringent food regulations as well as the high costs involved with solvent recovery systems. The literature on edible films can be classified into three types of coating solutes:

1. Aqueous soluble polymers such as proteins (milk, nut) and carbohydrates (starches, starch derivatives, gums).
2. Aqueous dispersion polymers such as latexes (e.g., Eudragits® based on acrylic copolymers) and pseudolatexes (e.g., Aquacoat ECD® based on ethyl cellulose).
3. Hot melt coatings such as lipids (fatty acids, polyglycerides and derivatives) and waxes (carnauba, beeswax, candelilla).

The choice of an appropriate coating material is influenced mainly by the specified core [9] and the ability of the coating material to impart the desirable characteristics to the product [10]. Although the performance of the coating material in the final application is crucial, matching of the material to the process technology and process conditions is likely to be of equal importance, and yet is almost certainly overlooked in practice. This lack of matching helps to explain why a large number of coating materials must typically be tested in order to determine their suitability when a product is developed [11]. To speed up product development, it is important to establish guidelines for polymer selection, based not only on their performance in the final application but also on their behaviour in a coating process.

5. Coating equipment

Modified fluidised beds are generally used in the food industry for granulation, drying and coating [2]. There are several different process arrangements for air-suspension particle coating. The liquid feed can be applied by using one of three modes: top-spray, bottom-spray and tangential-spray. Particle motion may be in a spouted bed, a vibro-bed, external recirculating beds or a Würster coater. For a comprehensive review of the operating principles, along with the advantages and disadvantages of the different coating equipment arrangements, the reader is referred to the works of [12–14].

The Würster-based fluid bed process is the preferred method for the application of functional coatings in the pharmaceutical