# متن خوانی انگلیسی

# Application of Spray dryers in food industry


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Spray drying is a common unit operation to convert liquid materials into powders for preservation, ease of storage, transport and handling and other economic considerations. The concept of spray drying was first recorded in a patent by Samuel Perry in 1872. This process was introduced for commercial purposes in the 1920s, and spray drying was fully established on a large-scale basis in the early 1980s (Masters, 1991, 2004).

Now, spray drying is a common practice in the food and dairy industries to make powders for capturing bioactive components and nutrients for a longer period of time. Besides the food and dairy industries, spray drying is used by many other industrial sectors such as the pharmaceutical, agrochemical, light and heavy chemicals, detergent, pigment, biotechnology and ceramic.

Among all food industries, the dairy industry is the largest sector to use spray drying for converting liquid milk and other milk-based products into a powder form. One of the unique characteristics of this process is that the production capacity of the spray drier can be as low as a few hundred grams of powder per hour, up to several tons per hour. The final product could be free- flowing powder of individual particles, agglomerates or granules. Since this unit operation provides a flexible and economical production approach and offers many advantages to the manufacturer, over 20000 spray driers are employed around the world for large-scale production of various powders (Mujumdar, 2004).

In spite of huge research and development progress, the energy requirement for spray drying operations is even now relatively high compared to other dehydration processes. The high-energy requirement is due to the fact that there is no mechanical dewatering involved during spray drying, since the majority of the water is removed using thermal energy only. The energy consumption for the evaporation of water during spray drying is reported to be 1.5 to 2 times higher than the expected latent heat of water evaporation . Freeze drying is a more energy-intensive operation compared to spray drying. The spray drier, being a convective drier, has a poor thermal efficiency unless very high inlet drying gas temperatures are used. The concentrated feed must be pumpable in order to dry. An exhaust gas stream from the drying chamber contains large amounts of low-grade waste heat, which is very difficult and expensive to recover at this stage due to the presence of particles in the stream. Another limitation of the spray drying operation is the high installation costs involved in setting up the plant.

## BASIC CONCEPTS OF SPRAY DRYING

Spray drying involves formation of droplets from the bulk liquid followed by the removal of moisture from the liquid droplets. The material in the liquid state is sprayed in the drying chamber, where the low-humidity hot gas (drying gas/medium) is mixed with the dispersed droplets. The spray of individual droplets is produced by the rotary wheel/disc atomizers, pressure nozzle or pneumatic-type atomizers. The atomizer is generally located at the top-centre of the drying chamber for most spray drying operations. The moisture, in the form of vapor, quickly evaporates from the suspended droplets due to simultaneous and fast heat and mass transfer processe. Spray drying is thus often referred to as a suspended droplet/particle processing technique. Drying of the droplets continues inside the drying chamber until the desired particle characteristics are achieved. The final dried product is produced using a single-stage drying process, schematically shown in Figure 1, for small to medium-scale spray drying operations. Separation of the dried particles from the drying gas and their subsequent collection take place in external equipment such as cyclones and/or bag-filter houses.

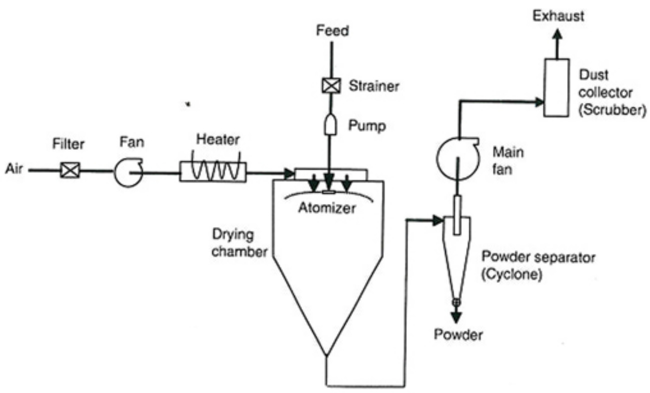


Fig. 1 A schematic diagram of a single-stage spray drying system

Modern large-scale spray driers are often equipped with internal and/or external fluid-beds, which maybe used for second-stage drying, cooling, agglomeration, granulation and/or coating of particulate materials. The rapid acceptance of the multi-stage drying technology has been due to the production of free-flowing and dust (very fine particles)-free powders, the contribution to economy improvement and the successful scale-up procedures. Extremely small particles (fines) are usually recovered from the cyclones, filter houses and fluidized-bed driers, and are sent to the top of the drying chamber for mixing with the freshly produced droplets. Mixing of fine particles with fresh droplets is beneficial where agglomerates are of interest.

The exhaust drying gas from the cyclone or filter house is discharged to the environment. Many times, scrubbers are installed to recover fines from the exhaust drying gas in order to meet environmental laws for minimizing pollution.

Spray drying can also be considered as an air humidification process. At ideal adiabatic conditions (assuming no heat losses), the temperature of the dry air during moisture evaporation will be reduced but the heat content of the air (dry air + vapor) will remain constant. The increased water vapor present in the air carries the lost energy from the dry air.

To produce a hot drying medium, the ambient air (at $T_{ambient}$) is heated to the desired temperature ($T_{inlet}$). In modern spray dries, the hot air stream is mixed with a cooling air stream (to keep the atomizer temperature at a low value) and a recycled air stream (containing fine particles) which is relatively cold. Therefore, the temperature of the hot air stream is usually kept slightly higher than the temperature required at the atomizer zone. During this heating, the absolute humidity of the air remains constant while its vapor pressure (relative humidity) is reduced to a very low value (near zero). The water activity of the dried product is normally reduced to less than 0.2; therefore the relative humidity of the air is maintained below %20 RH to reach the desired level of water activity. The outlet air temperature (Toutlet), which is controlled by the liquid flow, is regulated to keep the moisture or water activity of the product at the desired level. At the ent of the drying, the drying gas and the dried product can approach an equilibrium state. Therefore, the temperature of the product can be slightly lower than the outlet air temperature, whereas the vapor pressure of the water in the product can be slightly higher than the vapor pressure of the water in the air. For example, if the outlet air humidity is %15, the water activity of the product at the exit can be fixed at 0.2.

The rate of evaporation during spray drying is influenced by the temperature and vapor pressure differences between the surface of the droplets and the drying gas. The other important factors influencing the heat and mass transfer rates are diffusivity of water in air, relative velocity of droplet with respect to drying gas and the kinematic viscosity, the conductivity and heat capacity of air. The water can be diffused to the surface by the bulk liquid mobility or the vapor diffusion, depending on the feed type, physical form, composition, concentration, solvent type and drying medium conditions. The diffusion of water can be accompanied by the diffusion of certain solutes towards the surface of the droplets. This means that in a complex food system, certain components can be at higher concentrations towards the surface than at the centre of the droplets. During the earlier stages of drying, when the material moisture content is high, the liquid water diffusion mechanism dominates, whereas at low moisture content there might be both liquid diffusion and vapor diffusion or only vapor diffusion, depending on the type and other physical characteristics of the material being dried (Kundu et al., 2005; Zhang and Datta, 2004). The conversion of the liquid droplet to the dried particle is accompanied by an approximate weight loss of %50 (due to loss of water) and volume loss of %25 (due to shrinkage).

Bioactive ........ زیست فعال
Pharmaceutical ........ دارویی
Agrochemical ........ مواد شیمیایی-زراعی
Pigment ........ رنگدانه
Agglomerate ........ ماده متراکم
Dehydration ........ آبگیری، آب زدایی

Convective ........ همرفت
Simultaneous ........ همزمان
Humidification ........ رطوبت، رطوبت افزایی
Equilibrium ........ تعادل
Diffusivity ........ انتشار
Shrinkage ........ انقباض

منبع:


* Bhandari B.R., Patel K.C. and Chen X.D. Spray drying of food materials-process and product characteristics