An Overview of Spray Drying Technology for the Production of Fruit Juice Powders

Khalid Muzaffar and Pradyuman Kumar

Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Longowal, Punjab-148106, India
E-mail: khalidmuzaffar76@gmail.com

Abstract—*The spray drying process is considered a conventional method to convert fruit juices to powder form. Process of spray-drying consists of three basic steps, including atomization, droplet-hot air contact and moisture evaporation, and separation of dry product from the exit air. Spray drying of fruit juices involves the use of drying aid which minimizes the stickiness problem during drying operation. The paper gives an overview of the process of spray drying and its application in production of fruit juice powders.*

1. INTRODUCTION

Spray-drying is a unit operation by which a liquid product is atomized in a hot gas current to instantaneously obtain a powder. The spray-drying process has been developed in connection with the manufacture of dried milk. The initial liquid feeding the spray-dryer can be a solution, an emulsion or a suspension (Gharsallaoui et *al.,* 2007). The resulting dried product conforms to powders, granules or agglomerates, the form of which depends upon the physical and chemical properties of the feed and the dryer design and operation (Filkova *et al.,* 2007). The characteristics of spray-dried fruit juice and pulp powders depends on spray-drying conditions including concentration of drying aid used, inlet air temperature, feed flow rate, feed characteristics etc. (Chegini *et al.,* 2008). Spray-dryers come in different forms/patterns including cocurrent, counter current and mixed-flow. Cocurrent spray-dryers (where the feed droplets travel in the same direction as that of the drying gas flow) are most common and widely used dryers when compared to other systems (Zbicinski *et al.,* 2002).

2. STEPS INVOLVED IN SPRAY DRYING

The process of spray-drying consists of three steps: (a) atomization, (b) droplet-hot air contact and moisture evaporation and (c) separation of dry product from the exit air.

2.1. Atomization

Atomization is the most important stage in spray-drying process, which converts the fluid feed into tiny droplets/particles (Murugesan and Orsat, 2012). Due to the subsequent reduction in particle size and dispersion of the particles in the drying gas, the surface area of the particles increases exponentially. This increment in surface area of the particles helps to dry the feed in seconds. With the small size of droplets and the even distribution of the fluid feed, the moisture removal occurs without disturbing the integrity of the material. The atomization is achieved by atomizers which are generally classified as rotary atomizers, pressure nozzles, pneumatic nozzles and sonic nozzles (Cal and Sollohub, 2010). Atomizers are selected based upon the feed which needs to be dried and targeted final properties of the dried product as well as the particle size (Murugesan and Orsat, 2012).

2.2. Droplet-hot air contact and moisture evaporation

Atmospheric air is generally used as a drying medium in spray-drying process. During the spray-drying process, the atmospheric air is filtered through a filtering system and subsequently preheated according to the operating parameters. Sometimes, nitrogen or other inert gases are also used based upon the feed being dried and its instability, or sensitivity to oxygen (Cal and Sollohub, 2010). The drying of feed droplets after they come in contact with drying medium in a spray-drying process is a result of simultaneous heat and mass transfer. The heat from the drying medium is transferred to droplets by convection and then converted to latent heat during the evaporation of the droplet's moisture content. The rate of heat and mass transfer depends upon the droplet diameter and the relative velocity of the air and droplets (Murugesan and Orsat, 2012). The initial drying period starts in spray-drying once the droplet comes in contact with the drying medium. This is followed by the falling rate period where the rate of drying begins to decrease, and the period ends once the droplets reach their critical moisture content (Filkova *et al.,* 2007).

2.3. Separation of dry product from the exit air

Separation is often done through a cyclone placed outside the dryer which minimizes product losses in the atmosphere. Most dense particles are recovered at the base of the drying chamber

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while the finest ones pass through the cyclone to be separated from the humid exit air (Gharsallaoui *et al.*, 2007).

3. SPRAY-DRYING OF FRUIT JUICES

Among the drying techniques, spray drying is usually applied to produce the fruit juice powder. Spray drying of fruit juices is important in order to handle the market demand throughout the year. High moisture content in the fruit leads to have high water activity which can cause quality loss in fruits by increasing the chances of enzyme activity and microbial growth. Therefore, the reducing moisture content and water activity in fruits is always desirable to maintain the quality.

Spray-drying of sugar and acid rich fruit juices is problematic due to presence of low molecular weight sugars (glucose, fructose) and organic acids (citric, malic and tartaric acid) (Bhandari *et al.,* 1997). The high hygroscopicity, thermoplasticity, and low glass transition temperature (T_g) of these low-molecular-weight substances contribute to the stickiness problem. At a spray-drying temperature higher than $T_g + 20\ ^oC$, these components tend to form soft particle with a sticky surface, leading to powder stickiness and finally forming a paste-like structure instead of powder (Jing *et al.*, 2014). The molecular mobility of such molecules is high because of their low glass transition temperature (T_g) and thus leads to stickiness problem at temperatures normally prevailing in spray-dryers. The glass-transition temperature is the single most important parameter for assessing the ability of sugar and acid rich materials to be spray-dried (Imtiaz-Ul-Islam and Langrish, 2009; Bhandari et al., 1993).

To minimize the stickiness problem during spray-drying, high molecular weight drying aids are added to the feed material before being atomizing, so as to increase its glass transition temperature (Cabral *et al.*, 2009; Shrestha *et al.*, 2007; Santhalakshmy *et al.*, 2015). These drying aids not only overcome the stickiness problem and reduce powder hygroscopicity but also protect sensitive components of food material including phenolics, vitamins and caroteinoids (Ferrari *et al.*, 2012). Different drying aids such as maltodextrins, gum Arabic, modified starches and proteins are used in spray-drying to minimize the stickiness problem (Caliskan and Drim, 2013; Sahin-Nadeem, 2013; Rascon *et al.*, 2011). The decrease in powder stickiness during spray-drying using maltodextrins, gum Arabic and modified starches as drying aids is due to the increase in overall T_g of feed solids. Proteins as drying aids minimize the stickiness problem by modifying the surface properties of the atomized droplets and particles taking into consideration both the film forming and the surface activity of protein (Adhikari *et al.*, 2009). Because of the surface active and film forming property, protein migrates to the air water interface of atomized feed droplets, forming a protein film which is converted into a glassy skin with high glass transition temperature, when subjected into hot and dry air. The resultant skin is capable of overcoming the coalescence of droplets as well as sticky interactions of the particles at the drying chamber of the spray-dryer (Jayasundera *et al.*, 2011).

4. CONCLUSION

Spray drying is an important processing technology used to produce fruit juice powders. However stickiness of fruit juice powders occurs at temperatures normally prevailing in spray dryers. Stickiness problem during spray drying of fruit juices can be minimized by use of high molecular weight drying aids which increase the glass transition temperature of resulting powder.

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