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Production of Fruit Juice Powders by Spray Drying Technology

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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.

Keywords: Atomization, Drying aid, Fruit juice, Spray drying, Stickiness,

I. 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).

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

III 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. The foods that are spray-dried can be divided into two main groups viz. non-sticky and sticky. Non-sticky food materials can be easily spray-dried using a simple dryer design and the final powder remains free flowing. The examples of non sticky materials include egg powders, dairy powders and solutions such as maltodextrin, gums, and proteins (Tan *et al.*, 2011). In case of sticky foods, there occurs a problem in drying under normal spray-drying conditions. According to Bhandari and Howes (2005) and Hennings *et al.* (2001), the sticky foods generally get stick on the dryer wall or they may get transformed into unwanted agglomerates in the dryer chamber and conveying system which leads to operating problems and low product yield. The examples of sticky foods include sugar and acid-rich fruit juices and fruit pulp, honey etc. Powder stickiness is a cohesion-adhesion property. It can be explained in terms particle–particle stickiness (cohesion) and particle–wall surface stickiness (adhesion) (Papadakis and Bahu, 1992). The measure of the forces with which the powder particles are held together is due to its internal property called cohesion which leads to lump formation in the powder bed. Thus the force required to breakdown the powder agglomerates should be greater than the cohesive force (Mani *et al.*, 2002). Adhesion is an interfacial property and is the tendency of powder particles to stick with the wall surface of spray-dryer. The cohesion and adhesion forces are key parameters for design of dryers and drying conditions. Both stickiness characteristics (cohesion and adhesion) can co-exist during the spray-drying of sugar-rich food materials (Bhandari *et al.*, 1997; Adhikari, 2003). The inter particle stickiness i.e. cohesion is due to formation of immobile liquid bridges, mobile liquid bridges, mechanical interlocking namely intermolecular and electrostatic forces and solid bridges (Boonyai *et al.*, 2004). Adhesion of powder particles with the walls of drying chamber is the main cause for material loss in spray-drying of sugar and acid rich foods and the powder quality is reduced when retained for a longer time on walls of dryer (Maa *et al.*, 1998).

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). Maltodextrins are products of starch hydrolysis, consisting of D-glucose units linked mainly by *α* (1→4) glycosidic bonds. They are described by their dextrose equivalence (DE), which is inversely related to their average molecular weight (Bemiller and Whistler, 1996). Maltodextrins are low cost and very useful for spray drying process on food materials. Gum Arabic is natural plant exudates of Acacia trees, which consists of a complex heteropolysaccharide with highly ramified structure. It is the only gum used in food products that shows high solubility and low viscosity in aqueous solution, making easier the spray drying process (Rodriguez-Hernandez *et al*., 2005). 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).

IV. EFFECT OF SPRAY-DRYING PROCESS CONDITIONS ON PHYSICOCHEMICAL, MICROSTRUCTURAL AND ANTIOXIDANT PROPERTIES OF RESULTING POWDER

The characteristics of spray-dried 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).

Suhag and Nanda (2015) studied the effect of spray-drying process conditions to develop nutritionally rich honey powder using whey protein concentrate (WPC) as drying aid. The results revealed that increasing inlet air temperature lowered the bulk density, antioxidant activity, total phenolic content and vitamin C, but increased powder hygroscopicity. With increase in WPC concentration, there was increase in the bulk density and decrease in powder hygroscopicity. Increase in concentration of WPC showed positive effect on total phenolic content, antioxidant activity and retention of vitamin C in honey powder, which is related to superior encapsulation property of WPC and also prevented oxidative damage due to oxidation.

Wang *et al.* (2013) investigated the characteristics of soy sauce powders using whey protein isolate (WPI) and maltodextrin (MD) as drying aids. Soy sauce powders were prepared by spray-drying, using 5, 10 and 15% of WPI, respectively together with MD (35, 30 and 25%, respectively). The results showed that when just 5% WPI was added along with MD (35% MD + 5% WPI) to the feed solution, the product yield significantly increased by 20% compared to the control (40% MD). Results of scanning electron micrographs (SEM) showed that addition of WPI

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resulted in wrinkled particle surface, suggesting preferential migration of WPI to the particle surface. With the addition of WPI, cohesion index of soy sauce powders decreased, which is related to wrinkled or folded surface morphology offering less area of contact between particles, resulting in less inter-particle attraction and low chances of inter-particle bridging.

Fang and Bhandari (2012) studied the spray-drying of sugar rich bayberry juice using whey protein isolate (WPI) and maltodextrin (DE 10) as drying aids. No powder was recovered when the bayberry juice was spray-dried alone. A small amount of protein (1%) was efficient (powder recovery>50%) to spray dry the bayberry juice, while a large amount of maltodextrin (>30%) was needed for the same purpose. The authors revealed that the preferential migration of protein to the surface of droplets/particles, forming a glassy layer during drying reduced the adhesive behavior (stickiness) between particles and dryer wall during spray-drying of bayberry juice. The mechanism of maltodextrin to decrease the stickiness is due to the increase in the overall T_g of the bayberry juice powders. The authors reported low water activity of the powder at 5% (0.204) whey protein addition than at 1% (0.293) whey protein addition level which is related to water holding capacity of protein.

Tonon *et al.* (2008) studied the physicochemical properties of spray-dried acai pulp powder as influenced by spray-drying conditions. Results revealed that process yield was positively affected by inlet air temperature and negatively affected by feed flow rate, which are directly related to heat and mass transfer. Process yield was negatively influenced by higher drying aid concentration (maltodextrin), due to the increase in viscosity of feed mixture. Powder moisture content decreased with increase in inlet temperature while feed flow rate and maltodextrin concentration positively influenced the moisture content. Hygroscopicity of the powder decreased with increase in maltodextrin concentration and feed flow rate, and decrease in inlet air temperature. With respect to powder morphology, increase in inlet air temperature resulted in a greater number of particles with smooth surface and with larger sizes, due to the higher drying rates. The increase in carrier concentration also led to the production of larger particles, which is related to the increase in feed viscosity.

Mishra *et al.* (2014) studied the effect of drying aid concentration (maltodextrin) and inlet air temperature on the physicochemical properties of spray-dried amla juice powder. Moisture content and hygroscopicity of the powder were significantly affected by inlet air temperature and maltodextrin level. An increase in drying temperature and maltodextrin concentration decreased the free radical scavenging activity of the powder. Drying temperature and maltodextrin concentration also showed significant effect on total phenolic content of spray-dried amla juice powder.

Chegni *et al.* (2005) studied the effect of feed flow rate, atomizer speed, and inlet air temperature on various properties of spray-dried orange juice powder. The results indicated that increasing inlet air temperature increased the particle size, average time of wettability, and insoluble solids, and decreased the bulk density and moisture content of the powder. Increasing atomizer speed results in increasing the bulk density and average time of wettability of powder and decreases the particle size, moisture content and insoluble solids of powder. Increase in feed flow rate increased the bulk density, particle size, and moisture content of the powder and decreased the average time of wettability and insoluble solids of powder.

Ferrari *et al.* (2012) studied the effect of spray-drying conditions on the physicochemical characteristics of blackberry juice powder. A higher inlet air temperature significantly increased the hygroscopicity of the powder, decreased its moisture content, and led to the formation of larger particles with smooth surfaces. Powders produced with higher maltodextrin (DE 20) concentrations were less hygroscopic and had lower moisture content. The color of the blackberry juice powder was mainly affected by maltodextrin concentration, which led to the formation of powders that were whiter and less red as the concentration of maltodextrin increased. With respect to powder morphology, higher inlet air temperatures resulted in larger particles with smooth surfaces, whereas particles produced with lower maltodextrin concentrations were smaller.

Fazaeli et al., (2012) studied spray drying conditions and feed composition on the physical properties of black mulberry juice powder on moisture content, water activity, drying yield, bulk density, solubility, glass transition temperature (*T*g), and microstructure of spray dried black mulberry (*Morus nigra*) juice powder. A pilot-scale spray dryer was employed for the spray drying process and maltodextrin with different dextrose equivalent (6, 9, and 20DE) and gum Arabic were used as carrier agent. Independent variables were inlet air temperature (110, 130, and 150 ◦C), compressed air flow rate (400, 600, and 800 L/h), concentration of drying aids (8, 12, and 16%) and percent replacement of maltodextrin (6 and 9DE) by gum Arabic and maltodextrin 20DE (25, 50, and 75%). Between the different drying aids, maltodextrin 6DE shows the best effect on the properties of black mulberry juice powders. The process drying yield ranges from 45 to 82%. The highest drying yield (82%) and solubility (87%) refer to the blend of maltodextrin 6DE and gum Arabic. The lowest moisture content powders (1.5%) produced at the compressed air flow rate of 800 L/h. Inlet air temperature negatively influenced the bulk density due to the increase of powder's porosity. The lower the bulk density, the higher the solubility of powder is. With regard to morphology, powders produced with maltodextrin and gum Arabic presented the smallest size.

Muzaffar et al., studied the effect of drying aid concentration (maltodextrin) on Determination of production efficiency, color, glass transition, and sticky point temperature of spray dried pomegranate juice powder. Five different combinations of pomegranate juice and maltodextrin (95:5, 90:10, 85:15, 80:20 and 75:25 v/w) were prepared and spray dried in a laboratory-type spray dryer. Increase in concentration of maltodextrin significantly increased the powder recovery and 20% of maltodextrin was required for successful spray drying of pomegranate juice (powder recovery > 50%). Color values of pomegranate juice powder were significantly influenced by concentration of maltodextrin. With increase in concentration of maltodextrin powder, lightness (L* value) increased from 45.54 to 74.46, a* value decreased from 20.43 to 11.45 and b* value decreased from 2.16 to −3.83. Results showed that with increase in maltodextrin concentration from 5% to 25%, Tg increased from 38.23°C to

71.61°C. Sticky point temperature also showed an increase from 56.86 to 89.43°C with increase in concentration of maltodextrin.

V 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. The various characteristics of spray-dried fruit juice powders are well affected by spray-drying conditions including concentration of drying aid used, inlet air temperature, feed flow rate, feed characteristics etc.

REFERENCES

[1.] Gharsallaoui, G. Roudaut, O. Chambin, A. Voilley and R. Saurel, Applications of spray-drying in microencapsulation of food ingredients: An overview, Food Research International, 40, 2007, 1107–1121.

[2.] Filkova, L.X. Huang and A.S. Mujumdar, Industrial spray drying systems, In A. S. Mujumdar (Ed.), Handbook of industrial drying (3rd ed.). Boca Raton: CRC/Taylor & Francis, 2007..

[3.] G.R. Chegini, J. Khazaei, B. Ghobadian, and A.M. Goudarzi, Prediction of process and product parameters in an orange juice spray dryer using artificial neural networks, Journal of Food Engineering, 84, 2008, 534–543.

[4.] Zbicinski, C. Strumillo and A. Delag, Drying kinetics and particle residence time in spray drying. Drying Technology, 20, 2002, 1751-1768.

[5.] R. Murugesan and V. Orsat, Spray Drying for the Production of Nutraceutical ingredients—A Review, Food Bioprocess Technology 5, 2012, 3–14.

[6.] K. Cal and K. Sollohub, Spray drying technique. I: hardware and process parameters, J. Pharm. Sci. 99, 2010, 575-586.

[7.] Bhandari and T. Howes, Relating the stickiness property of foods undergoing drying and dried products to their surface energetic, Drying Technology, 23, 2005, 781-797.

[8.] Hennings, T.K. Kockel and T.A.G. Langrish, New measurements of the sticky behavior of skim milk powder, Drying Technology, 19, 2001, 471-484.

[9.] S.E. Papadakis and R.E. Bahu, The sticky issues of drying, Drying Technology, 10, 1992, 817-837.

[10.] S. Mani, S. Jaya and H. Das, Sticky Issues on Spray Drying of Fruit Juices, ASAE/CSAE North-Central Intersectional Meeting, 2002.

[11.] B.R. Bhandari, N. Data and T. Howes, Problems associated with spray drying of sugar-rich foods, Drying Technology, 15, 1997, 671–684.

[12.] B. Adhikari, Drying Kinetics and Stickiness of Single Drop of Sugar and Acid-Rich Solutions, (PhD thesis) Chemical Engineering. The University of Queensland, Australia, 2003.

[13.] P. Boonyai, B. Bhandari, and T. Howes, Stickiness measurement techniques for food powders: a review, Powder Technology, 145, 2004, 34-46.

[14.] Y.F. Maa, P.A. Nguyen, K. Sit, and C.C. Hsu, Spray-drying performance of a bench-top spray dryer for protein aerosol powder preparation, Biotechnology and Bioengineering 60, 1998, 301-309.

[15.] Du. Jing, Z.Z. Ge, Z. Xu, B. Zou, Y. Zhang and C.M. Li, Comparison of the Efficiency of Five Different Drying Carriers on the Spray Drying of Persimmon Pulp Powders, Drying Technology, 32, 2014, 1157-1166.

[16.] M.D. Imtiaz-Ul-Islam and T.A.G. Langrish, Comparing the crystallization of sucrose and lactose in spray dryers, Food Bioproduct and Processing 87, 2009, 87-95.

[17.] B.R. Bhandari, A. Senoussi, E.D. Dumoulin and A. Lebert, Spray drying of concentrated fruit juices, Drying Technology 11, 1993, 1081-1092

[18.] A.C.S. Cabral, S. Said and W.P. Oliveira, Retention of the enzymatic activity and product properties during spray drying of pineapple stem extract in presence of maltodextrin, International Journal of Food Properties, 12, 2009, 536–548.

[19.] A.K. Shrestha, T. Ua-arak, B.R. Adhikari, T. Howes and B.R. Bhandari, Glass transition behavior of spray dried orange juice powder measured by differential scanning calorimetry (DSC) and thermal mechanical compression test (TMCT), International Journal of Food Properties, 10, 2007, 661-673

[20.] S. Santhalakshmy, S.J.D. Bosco, S. Francis, and M. Sabeena, Effect of inlet temperature on physicochemical properties of spray-dried jamun fruit juice powder, Powder Technology 274, 2015, 37-43.

[21.] G. Caliskan and S.N. Dirim, The effects of the different drying conditions and the amounts of maltodextrin addition during spray drying of sumac extract, Food Bioproduct and Processing, 91, 2013, 539-548.

[22.] H. Sahin-Nadeem, C. Dincer, M. Torun, A. Topuz and F. Ozdemir, Influence of inlet air temperature and carrier material on the production of instant soluble sage (Salvia fruticosa Miller) by spray drying, LWT - Food Science and Technology, 52, 2013, 31-38.

[23.] M.P. Rascon, C.I. Beristain, H.S. García and M.A. Salgado, Carotenoid retention and storage stability of spray-dried encapsulated paprika oleoresin using gum Arabic and soy protein isolate as wall materials, LWT- Food Science and Technology, 44, 2011, 549–557.

[24.] J.N. Bemiller and R.L. Whistler, Carbohydrates. In: Fenema, O. (Ed). Food Chemistry. Marcel Dekker, New York, 1996.

[25.] G.R. Rodriguez-Hernandez, R. Gonzalez-Garcia, A. Grajales-Lagunes, and M.A. Ruiz-Cabrera, Spray-drying of cactus pear juice (Opuntia streptacantha): Effect on the physicochemical properties of powder and reconstituted product, Drying Technology 23, 2005, 955–973.

[26.] G.R. Chegini, J. Khazaei, B. Ghobadian and A.M. Goudarzi, Prediction of process and product parameters in an orange juice spray dryer using artificial neural networks. Journal of Food Engineering, 84, 2008, 534–543.

[27.] B. Adhikari, T. Howes, B.R. Bhandari and T.A.G. Langrish, Effect of addition of proteins on the production of amorphous sucrose powder through spray drying, Journal of Food Engineering, 94, 2009, 144–153.

[28.] M. Jayasundera, B. Adhikari, R. Adhikari and P. Aldred, The effect of protein types and low molecular weight surfactants on spray drying of sugar rich foods, Food Hydrocolloids, 25, 2011, 459-469.

[29.] Y. Suhag and V. Nanda, Optimisation of process parameters to develop nutritionally rich spray-dried honey powder with vitamin C content and antioxidant properties, International Journal of Food Science and Technology, 50, 2015, 1771–1777.

[30.] W. Wang, Y. Jiang and W. Zhou, Characteristics of soy sauce powders spray-dried using whey proteins and maltodextrin as drying aids, Journal of Food Engineering, 119, 2013**,** 724-730.

[31.] Z. Fang and B. Bhandari, Comparing the efficiency of protein and maltodextrin on spray drying of bayberry juice, Food Research International, 48, 2012, 478–483.

[32.] R.V., Tonon, C. Brabet, and M.D. Hubinger, Influence of process conditions on the physicochemical properties of acai powder produced by spray drying, Journal of Food Engineering, 88, 2008, 411-418.

[33.] P. Mishra, S. Mishra and C.L. Mahanta, Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of alma (Emblica officinalis) juice powder, Food Bioproduct and Processing, 92, 2014, 252–258.

[34.] G.R. Chegini and B. Ghobadian, Effect of spray-drying conditions on physical properties of orange juice powder, Drying Technology, 23, 2005, 657-668.

[35.] C.C. Ferrari, S.P.M. Germer and J.M. de Aguirre, Effects of spray-drying conditions on the physicochemical properties of blackberry powder, Drying Technology, 30, 2012, 154-163.