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Spray Drying–An Innovation in Fruit and Vegetable Dehydration–A Review

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Abstract—*Dehydration, a versatile and wide spread technology, has attained newer dimensions with several innovations to reduce the energy utilization and operational cost. Among them spray drying offers greater scope for the production of good quality fruit and vegetable powders. Spray drying is the transformation of feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium, used commercially for the production of food powders due to its effectiveness under optimum condition. Spray drying yields food powders using a spray drier in a single step process. The main objective of spray drying is to get most rapid liquid removal with minimal negative impact on product, with low water activity and reduced weight, resulting in easy storage and transportation. Spray drying involves different steps like concentration of fruit juice, atomization, droplet – air contact, droplet drying and finally dried particle separation. This process also depends on several factors like inlet temperature, air flow rate, feed flow rate, atomizer speed etc. of which inlet temperature is the most important factor which affects several parameters like moisture content, particle density, bulk density, yield, hygroscopicity and pigment degradation of the final product. Food powders on reconstitution gives ready to drink fresh like beverage. The different steps of spray drying its advantages and factors involved in this process are reviewed in this paper.*

1. INTRODUCTION

India bestowed with diverse agro climatic conditions, grows almost all kinds of fruits and vegetables has become the 2nd largest producer of it [19]. But, a sizeable amount of 18.0% of fruits and 12.7% of vegetables are getting spoiled [13]. Thus, it needs due attention for harnessing complete potential of our country's produce through appropriate post-harvest management practices in a holistic manner. Value addition of the produce suggests a greater scope for elevating the utilisation of fruits and vegetables into development of quality products. Drying is an oldest, simplest and the cheapest method of value addition.

'Drying' and 'dehydration' means removal of water, the former being done under the influence of solar energy or wind and the latter by the application of artificial heat under controlled conditions of temperature, humidity and air flow [28]. Pre-drying treatments include raw material selection, washing, peeling, size reduction, blanching, sulphuring etc. A wide array of novel drying techniques are now available and the choice of a suitable one depends upon various factors such as type of product, availability of dryer, cost of dehydration and final quality of desiccated product. Among them spray drying offers greater scope for the production of good quality fruit and vegetable powders. The different steps of spray drying its advantages and factors involved in this process are reviewed in this paper.

2. SPRAY DRYING

Novel drying technologies include osmotic dehydration, spray drying, freeze drying, microwave drying, infra-red radiation drying, electric or magnetic field drying, superheated steam drying, explosion puffing, foam mat drying and acoustic drying [14].

Spray drying is the transformation of feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium, used commercially for the production of food powders due to its effectiveness under optimum condition [15]. It involves evaporation of moisture from an atomized feed by mixing the spray and the drying medium (air). The drying proceeds until the desired moisture content is reached in the sprayed particles and the product is then separated from the air. The mixture being sprayed can be a solvent, emulsion, suspension or dispersion. The main objective of spray drying is to get most rapid liquid removal with minimal negative impact on product, with low water activity and reduced weight, resulting in easy storage and transportation [1].

3. STEPS IN SPRAY DRYING

According to Phisut [24] spray drying comprises 5 basic steps viz., concentration of fruit juice, atomisation, droplet - air contact, droplet drying and dried particle separation.

3.1 Concentration of fruit juice

Feed stock has to be concentrated to 50- 60% before introducing to spray dryer [5]. Concentrated juice has increased solid content thereby reduces the amount of liquid to be dried.

3.2 Atomisation

This refers to conversion of bulk liquid into a spray or mist by passing liquid through a nozzle. Liquid is dispersed into fine droplets of size- 20-180 micro meter (depending on nozzle), surface area of the liquid increases [23].

3.3 Droplet – air contact

This is an important matter which defines the method of spray drying. The important component of spray dryer is the chamber where the sprayed droplet contacted with the hot air and the drying process begins. Air is heated outside the chamber to a predefined temperature depending upon the characteristics of the feed fluid [10]. Based on the ways of air-droplet contact there are three methods of spray drying.

- **Co - current flow:** Material is sprayed in the same direction of flow of hot air. The product is treated with care due to sudden vaporization.
- **Counter current flow:** Material is sprayed in the opposite direction of the flow of hot air (upwards). This is suited only to thermally stable products.
- **Combined flow:** The product is sprayed upwards and only remains in hot zone for a short time. Gravity then pulls the product into a cooler zone.

The thermal energy of the hot air is used for evaporation and the cooled air pneumatically conveys the dried particles in the system. The contact time of the hot air and the spray droplets is only a few seconds. Once the drying is achieved and the air temperature of air drops instantaneously.

3.4 Droplet drying

When spray droplets come into contact with drying air, evaporation takes place. Due to high specific surface area, existing temperature and moisture gradients, an intense heat and mass transfer results in efficient drying. Evaporation can lead to cooling of droplet. When the droplet water content reaches a critical value, a dry crust is formed at the droplet surface and the drying rate rapidly decreases. Drying is finished when the particle temperature becomes equal to that of the air.

3.5 Dried particle separation

The dense particles are recovered at the base of the drying chamber while the finest ones pass through the cyclone to separate from the humid air. Spray dryers are also equipped with the filters, called ‘‘bag houses’’ - to remove the finest powder or “chemical scrubbers”- to remove the remaining powder or any volatile pollutants (e.g. flavourings).

4. PARAMETERS INFLUENCING SPRAY DRYING

Success of drying depends on several parameters [20] like, inlet temperature, air flow rate, feed flow rate, atomizer speed, type of carrier agent and its concentration, which are to be optimized depending on the feed material.

4.1 Inlet temperature

Temperature of the heated drying air is called ‘inlet temperature’. Temperature of the air with the solid particles before entering the cyclone is designated as ‘outlet temperature’. Usually, an inlet temperature of 150-220^{0}C and an outlet temperature of 50-80^{0}C is maintained. Solval *et al*. [27] reported that *Cucumis melo* powder produced at inlet temperature of 170°C had higher moisture content, water activity, β-carotene content and vitamin C. Bastos *et al*. [2] could spray dry cashew apple juice at inlet temperature of 185^{o}C, outlet temperature of 81.5^{o}C. Inlet temperature is the most important factor which affects the different parameters of the product viz., bulk density, particle size, moisture content, hygroscopicity, pigment degradation and yield.

4.1. a. Inlet temperature affects moisture content

At a constant feed flow rate, increasing the inlet air temperature reduced the residual moisture content. This is observed by Chegini and Ghobadian [6] in orange juice powder, Quek *et al*. [25] in watermelon juice, Goula and Adamopoulos [12] in tomato juice and Jittanit *et al*. [15] in pineapple juice.

4.1. b. Inlet temperature affects bulk density

An increase in the inlet air temperature often results in a rapid formation of dried layer on the droplet surface and it causes the skinning over or casehardening on the droplets at the higher temperatures. Thus, bulk density increases. This leads to the formation of vapor-impermeable films on the droplet surface, followed by the formation of vapour bubbles and, consequently the droplet expansion [29].

4.1. c. Inlet temperature affects particle size

The use of higher inlet air temperature leads to the production of larger particles and causes the higher swelling and thus increases particle size [26].

4.1.d. Inlet temperature affects hygroscopisity

The higher drying temperature the lower the moisture content of product and higher its hygroscopicity. It is in agreement with the spray drying of tomato pulp by Goula & Adamopoulos [11]. Ferrari *et al.* [9] reported higher hygroscopicity with higher inlet temperatures in black berry fruit powder production.

4.1.e. Inlet temperature affects yield

The increase of inlet temperatures has given the higher process yield due to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures were used.

4.1.f. Inlet temperature affects pigments

Pigment degradation can occur due to thermal degradation and oxidation. Quek *et al*. [25] studied the effect of inlet temperature (145-175^{0}C) on the stability of lycopene and B-carotene in watermelon juice powder. The result showed that, lycopene content was decreased with the inlet temperature. A similar observation was reported in the spray drying of tomato pulp [5]. In addition, inlet temperature was affected the stability of anthocyanin in the acai juice powder [29].

4.2 Air – flow rate

A lower air flow rate causes an increase in the product halting time in drying chamber and lead to greater moisture removal. But a rise in air flow rate lead to high powder moisture content and decrease in powder solubility [22].

4.3 Feed – flow rate

Higher flow rates imply in a shorter contact time between droplet and drying air and heat transfer will be less efficient and thus caused the lower water evaporation. At constant atomizer speed, increasing the feed flow rate, more liquid was atomized into chamber, thus time of drying was reduced and finally the drying was incorrect [24].

4.4 Atomiser speed

The increased atomizer speed spread the liquid into thin film layer and thus caused the smaller droplet and particle size.

For fruit juice powder production several problems like, stickiness of powder, hygroscopicity, low solubility and problem related to fruit juice natural characteristic that caused no powder production may appear [5]. Some possible consequences are related to impaired product stability, decreased yields and even operating problems to spray drier [3]. For preventing of stickiness and production of powder two ways can be adopted, using of drying agent material and using of specific equipment to facilitate the powder handling [5]. Addition of maltodextrin to mango juice was optimized with the ratio of 55:45 (fruit solid: maltodextrin) and a modified spray dryer with rotating air broom system reduced the stickiness of banana powder by 30% [17].

4.5 Carrier agent

Stickiness can be avoided by using high molecular weight drying aids which increases the glass transition temperature of the product [4].

4.5.1 Type of carrier agent

Carrier agent materials include corn syrup, natural gums, sucrose, maltodextrins etc. caused powder production and cohesion of partilces on spray drier wall [7]. Goula and Adamopoulos [12] studied the effect of maltodextrin addition on the properties of tomato powder and reported that the higher the maltodextrin dextrose equivalent higher the moisture content in the powder. Yousefi *et al*. [32] studied the effect of carrier agents such as maltodextrin, gum arabic and waxy starch on the solubility of the pomegranate juice powder. The result showed a lowest solubility in pomegranate juice powder by waxy starch. Powder from gum arabic showed the less amorphous behavior when compared with the waxy starch and maltodextrin.

4.5.2 Concentration of carrier agents

Quek *et al*. [25] investigated the effect of maltodextrin concentrations (0, 3 and 5%) on the properties of the watermelon juice powder and reported that the addition of 5% maltodextrin to the feed appeared to give better results than addition of 3% maltodextrin. Jittanit *et al.* [15] reported that the increase of maltodextrin concentration resulted in decreased moisture content of pineapple juice powder and the optimum concentration of MD (DE 10) was 15% of the volume of the total feed solution. Product recovery increased when the maltodextrin in the feed was increased, from 40 % to 60% in lime juice powder production with larger particle size and higher bulk density [33].

4.5.3 Alternative carrier agents

Addition of large amounts of drying aids increases the cost and may alter the original flavour and taste of the product, and risk consumer disapproval demanded the need of alternative drying aids like proteins.

A small amount of whey protein isolate (1%) could efficiently overcome the stickiness problem, where a large amount of maltodextrin (>30%) was needed [8]. Wang *et al*. [30] reported that whey protein has been widely applied in SD since it functions as a wall material on the particle surface to prevent oxidative damage and release of the core materials. When 5% WPI was added in the feed solution along with 35% malto dextrin, the soy sauce powder yield was significantly increased by 20% compared to the control (40% maltodextrin).

Oliveira *et al*. [21] attempted to totally or partially replace maltodextrin (DE10) by cashew tree gum (CTG) as a drying aid agent in spray drying of cashew apple juice. The most adequate drying conditions (D/C=5, CTGR≥50%) resulted in more than 90% of ascorbic acid retention, and produced a powder with good flowing properties and water solubility.

Bastos *et al*. [2] spray dried cashew apple juice with juice: encapsulating agent (1.5% chitosan + 12% WPI) ratio (1:1, 1:1.5, 1:2) and found no significant difference in yield and vitamin C content of the powders among treatments. The product remained stable even after five months of storage at room temperature.

5. PACKAGING AND STORAGE

Maya [18] reported that use of metalised LDPE packs and N2 flushing assured a shelf life of 4 months for the sapota milk beverage powder under ambient conditions. The shelf life studies of spray dried betalain dye powder, for 180 days showed that the dye is quite suitable in the temperature range of -4 to 20^0C [16].

6. RECONSTITUTION

Xiang *et al.* [31] prepared papaya beverage with the best proportion of spray dried papaya powder, saccharose and citric acid of 10:2:0.05 and the ratio of the mixed powder to water of 1:6. Maya [18] reported that 30 g sapota milk beverage powder can be mixed with 1 glass of chilled water to obtain a thicker chikoo shake.

7. CONCLUSION

In short, spray driers can dry a product very quickly and also turn a solution or slurry into a dried powder in a single step, which is advantageous for maximizing the profit and minimizing the process. Other benefits include hygienic conditions during processing, short contact time, minimal negative impact on product, with low water activity and reduced weight, resulting in easy storage and transportation. Finally, it can be reconstituted like original juice.

REFERENCES

[1] Adhikari, B., Howes, T., Bhandari, B.R., and Troung, V., Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods convective drying: Experiments and modelling, *Journal of Food Engineering,* 2004, 62, pp. 53-68.

[2] Bastos, D. S., Goncalves, M. P., Andrade, C. T., Araujo, K. G. L., and Leao, M. H. M. R., Microencapsulation of cashew apple (*Anacardium occidentale* L.) juice using a new chitosan-commercial bovine whey protein isolate system in spray drying, *Food Bioproduct. Processing,* 2012, 90, pp. 683-692.

[3] Bhandari, B.R., Datta, N., and Howes, T., Problem associated with spray drying of sugar- rich foods, *Drying technology,* 1997, 15, pp. 671-684.

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

[5] Chegini, R.G., and Ghobadian, B., Spray dryer parameters for fruit juice drying, *World Journal of Agricultural Science,* 2007, 3, pp. 230-236.

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

[7] Dolinsky, A., Maletskaya, Y., and Snezhkin, Y., Fruit and vegetable powders production technology on the basis of spray and convective drying methods, *Drying Technology,* 2000, 18, pp. 747-758.

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

[9] Ferrari, C.C., Ribeiro, C. P., and Aguirre, J. M., Spray drying of blackberry pulp using maltodextrin as carrier agent, *Brazilian Journal of Food Technology,* 2012, 15(2), pp. 157-165.

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

[11] Goula, A.M., and Adamopoulos, K.G., Stability of lycopene during spray drying of tomato pulp, *Food Science and Technology,* 2005, 38, pp. 479–487.

[12] Goula, A.M., and Adamopoulos, K.G., Effect of maltodextrin addition during spray drying of tomato pulp in dehumidified air: powder properties, *Drying Technology,* 2008, 26, pp. 726-737.

[13] ICAR (Indian Council of Agricultural Research), Annual report 2011-'12, ICAR, New Delhi, 2012, 205p.

[14] Jayaraman, K.S., and Gupta, D.K., Drying of fruits and vegetables, In. Mujumdar, A.S. (Ed.) *Handbook of industrial drying,* Marcel Dekker, New York, USA, 1995, pp. 643-690.

[15] Jittanit, W., Niti-Att, S., and Techanuntachikul, O., Study of spray drying of pineapple juice using maltodextrin as an adjunct, *Chiang Mai Journal of Science,* 2010, 37(3), pp. 498-506.

[16] Koul, V.K., Jain, M.B., Koul, S., Sharma, V.K., Tikoo, L.C., and Jain, M.S., Spray drying of beetroot juice using different carriers, *Indian Journal of Chemical Technology,* 2002, 9, pp. 442-445.

[17] Mani, S., Jaya, S., and Das, H., Sticky Issues on Spray Drying of Fruit Juices, ASAE/CSAE North-Central Intersectional Meeting, September 27-28, 2002, Saskatchewan, Canada., *Abstract*: 42.

[18] Maya., Value addition in sapota. MSc. thesis. Kerala Agriculture University, Thrichur, 2004, 156p.

[19] NHB (National Horticulture Board), Indian Horticulture Database, National Horticulture Board, Government of India, Gurgaon, India, 2012, 195p.

[20] Obon, J.M., Castellar, M.R., Alacid, M., and Lopez, F.J.A., Production of a red-purple food colorant from *Opuntia stricta* fruits by spray drying and its application in food model systems, *Journal of Food Engineering,* 2009, 90, pp. 471–479.

[21] Oliveira, A.R.G., Maia, A.G., Figueiredo, W.R., DeSouza, R.C.A., Brito, S.E., and Azeredo, C.M.H., Addition of cashew tree gum to maltodextrin based carriers for spray drying of cashew apple juice, *International Journal of Food Science and Technology,* 2009, 44, pp. 641–645.

[22] Papadakis, S.E., Gardeli, C., and Tzia, C., Raisin extract powder: Production, physical and sensory properties, *Proceedings of the 11th international drying symposium*, IDS-1998, Halkidiki, Greece, 1998, 67p.

[23] Patel, R.P., Patel, P.M., and Suthar, M.A., Spray drying technology: an overview, *Indian Journal of Science and Technology,* 2009, 10, pp. 44-47.

[24] Phisut, N., Spray drying technique of fruit juice powder: some factors influencing the properties of product, *International Food Research Journal,* 2012, 19(4), pp. 1297-1306.

[25] Quek, Y.S., Chok, N.K., and Swedlund, P., The physicochemical properties of spray-dried watermelon powders, *Chemical Engineering and Processing,* 2007, 46, pp. 386-392.

[26] Reineccius, G.A., Multiple-core encapsulation - the spray drying of food ingredients, In. Vilstrup, P. (Ed.) *Microencapsulation of Food Ingredients*, Leatherhead Publishing, Surrey, U.K., 2001, pp. 546-562.

[27] Solval, K. M., Sundararajan, S., Alfaro, L., and Sathivel, S., Development of cantaloupe *(Cucumis melo)* juice powders using spray drying technology, *Food Science and Technology,* 2012, 46(1), pp. 287-293.

[28] Srivastava, R.P., and Kumar, S., *Fruit and vegetable preservation- principles and practices*, International Book Distributing Co., Lucknow, 2012, 474p.

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

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

[31] Xiang, C.Q., Wei, H., ShengNan, W., and QiuXiong, Y., Spray drying processing technology of papaya powder, *Modern Food Science and Technology,* 2009, 25(1), pp. 68-72.

[32] Yousefi, S., Djomeh, E, Z., and Mousavi, M.S., Effect of carrier type and spray drying on the physicochemical properties of powdered and reconstituted pomegranate juice (*Punica granatum* L.), *Journal of Food Science and Technology,* 2011, 48, pp. 677-684.

[33] Zareifard, M. R., Niakousari, M., Shokrollahi, Z., and Javadian, S., A feasibility study on the drying of lime juice: the relationship between the key operating parameters of a small laboratory spray dryer and product quality, *Food Bioprocess Technology,* 2012, 5(5), pp. 1896-1906.