Journal of Chemical Process and Material Technology
http://publikasiilmiahunwahas Hamad et.al., vol(1), 37-44, 2022

Comparison of Physical and Chemical Changes of Dried Berries Fruits Powders from Spray and Freeze Drying

Alwani Hamad[1]*, Afwa Hayuningtyas[2], Pinyapat Jitphongsaikul[3]
[1]Department of Chemical Engineering, Faculty of Engineering and Science, Universitas Muhammadiyah Purwokerto, Indonesia
[2]Department of Nutrition, Faculty of Public Health, Universitas Teuku Umar, Aceh, Indonesia
[3]Department of Food Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand
*Corresponding Author: alwanihamad@ump.ac.id

ABSTRACT
The different drying methods for preserving fruits may affect fruits' physical and chemical properties, especially dried berries. The expected drying techniques include Spray Drying (SD) and Freeze Drying (FD). The physical characteristics, such as color, taste/odor, and thermal properties, have changed during the process. The higher temperatures in spray drying may affect the phytochemical compounds that will change the final nutritional value. The juice taste and color of berries powders that FD produces are better than SD. However, the morphology of powder that resulted from SD is better. Also, the losses of phenolic compound and anthocyanin content of dried berries produced from SD are much lower than FD. Therefore, the choices of higher quality dried berries can be produced by FD that are suitable to preserve the phytochemical compounds that have health benefits.

Keywords: Drying, Spray Drying, Freeze Drying, Powder, Dried Berries

INTRODUCTION

Fruits are a useful phytochemical that is an essential functional food product in the dried fruits industry. The production of fruit powders involves the drying of high-moisture fresh fruits. Drying is an energy-intensive food processing operation that plays a significant role in product quality (Shishir and Chen, 2017). Increased competition in today's global market means that avenues to improve process efficiency and product quality are desirable. In order to do this, it is crucial to understand the physical and chemical changes occurring during drying in different methods. Thus, the investigation of the changes of the characters of berries during drying will give some knowledge to food industry in applying drying methods. A lot of drying process has been applied to preserve fruits product. This paper only determined two drying methods (spray and freeze drying) for governing changes in the dried product, especially in berry fruits powders.

DRYING PROCESS

The way to remove water from food material is called dehydration. Dehydration is one of the ancient food processing techniques. Dehydration means completely removing water under controlled conditions so that minimal changes occur in the food item (Fellows P.J., 2009; Mohammed *et al.*, 2020). The important reason for dehydration is a reduction of the natural water content below the level critical for the growth of microorganisms (12-15%), or the final dried product has water activity less than 0.6, without being detrimental to important nutrients(Fellows P.J., 2009; Romano *et al.*, 2018). Also, it is aimed at preserving flavor, aroma, appearance, and the ability to regain the original shape or appearance on reconstitution with water. However, the dehydration process is also accompanied by significant alterations. There is a concentration on primary ingredients such as proteins, carbohydrates, and minerals. It will occur along with some chemical changes(Fellows P.J., 2009; Nayak, Liu and Tang, 2015).

Drying is categorized as one type of dehydration with heat involvement. Drying removes free water from food material to reduce the water activity of food products by evaporation or sublimation (freeze-drying). The drying process involves heat and mass transfer between food materials and the drying medium. The heat can be supplied in different ways, such as conduction, convection, radiation, or even microwave heating (Fellows P.J., 2009).

Drying of food material occurs when water vapor is removed from its surface into the surrounding space, resulting in a relatively dried form of the materials. However, water or moisture can be moved to the surface of food material in different ways; there are fluid movements by capillary forces, diffusion of liquids caused by differences in the concentration of solutes in other regions of the food, and diffusion of liquid which are adsorbed in layers at the surfaces of the solid component of the food. These mechanisms affect physical and chemical changes in the final dried product (Fellows P.J., 2009; Ray, Raychaudhuri and Chakraborty, 2016; Ho *et al.*, 2019)

Drying is one of the oldest preservation methods for food materials. The technologies of the drying may be classified as the mechanisms or dying medium that used such as from the oldest technique such as hot air drying to the modern ones like microwave vacuum drying (Ray, Raychaudhuri and Chakraborty, 2016). This article will only determine two critical drying processes: spray drying and freeze-drying. Also, it was picked for the study case in dried blueberry.

SPRAY DRYING

Spray drying is a process that converts liquid into materials into powders for preservation, ease of storage, transport, and handling. Spray drying is a common practice in the food and dairy industries. It employs hot air as the drying medium, and the dying time is fast (Fellows P.J., 2009; Normand *et al.*, 2013). The schematic of the spray drying equipment and principles of spray drying is in Figure 1.

In the spray drying, the droplet will be injected into the nozzle of the spray drying machine and turned into the Spray. The droplet sprayed will contact the hot air that comes through the drying chamber, transforming the heat and mass. The heat will flow into droplets, make the water vapor, and move out of the crust solid. The mass transfer is water in droplets into hot air resulting in dry particles called powders. The drying medium usually uses hot air at 150 – 250 C (inlet temperature). The hot air will transfer the dry product that falls into the bottom of the dry chamber to the cyclone part to separate the product from the hot air. Thus, the hot air will be moved into the upper part of the cyclone through the air filter (Normand *et al.*, 2013; Shishir and Chen, 2017).

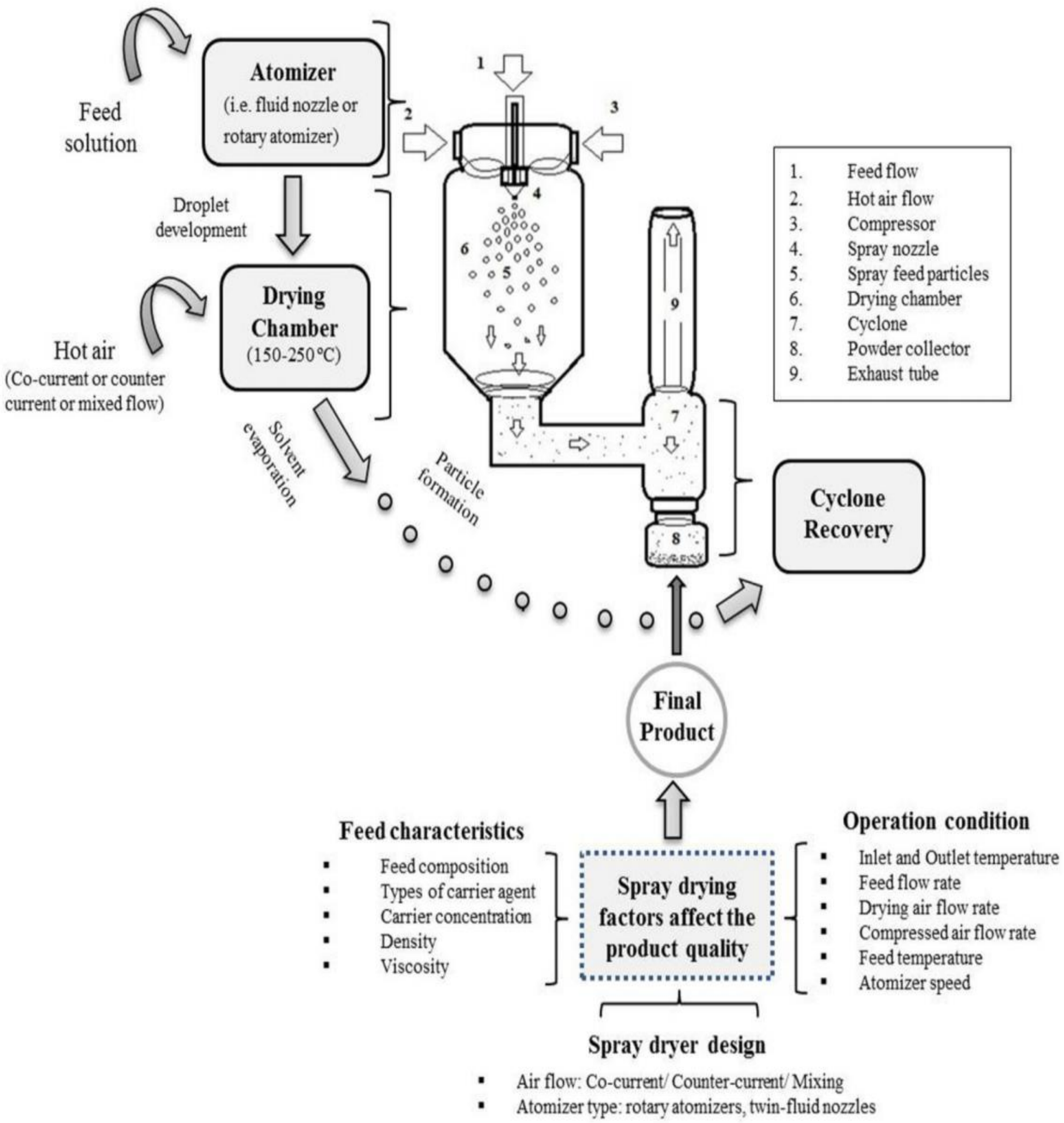

Figure 1. the schematic of the spray drying process (Shishir and Chen, 2017; Dantas *et al.*, 2018; Ocampo-Salinas *et al.*, 2020)

FREEZE DRYING

Freeze drying of food is the method of water removal using the sublimation process to eliminate the water. The process takes place under levels of vacuum and at a lower temperature than other drying methods. In order to understand the principles of freeze drying, it needs to understand the state of water. The phase diagram (Figure 2) of water represents the changing state of water when pressure and temperature are changed. The C-D line shows the passage from solid to vapor (sublimation). Freeze drying employs total pressure apply in the range of 0.001 – 1 torr and temperature of -80 ^{o}C to 35 ^{o}C. Heat is supplied by conduction/radiation to sublime ice into vapor. The process of freeze drying is divided into three stages. There are freezing processes followed by the primary drying process (sublimation) and the secondary drying process (desorption)(Fellows P.J., 2009; Chranioti *et al.*, 2016; Eun *et al.*, 2020).

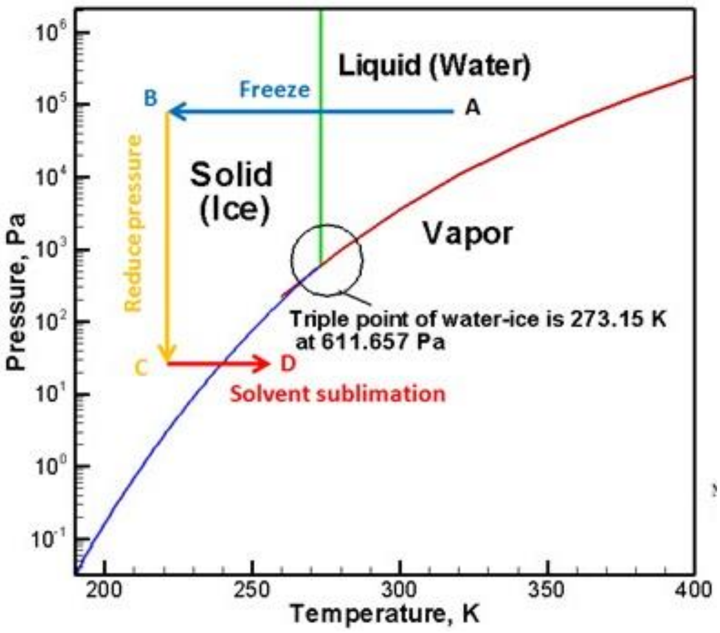

Figure 2. The phase diagram represents a freeze-drying process (Alexeenko, A Ganguly, 2009)

PHYSICAL AND CHEMICAL CHANGES OF FOOD AFTER SPRAY AND FREEZE DRYING

The impact of the drying process can be categorized as the changes in structures, color, tastes/ odor, nutrition value, and thermal properties of materials (Fellows P.J., 2009; Fang and Bhandari, 2010). The drying process's primary effect is the food materials' physical properties. They can be changed during drying when heat is involved, and water is removed. The food component creates a new food structure that occurs naturally or results from processing. During the drying process, the changes in physical properties are liquid turning into solid and high water content turning into solid. Therefore, it changes deformation and flow properties. Also, the dried product is difficult to flow, thus having a higher viscosity and changes in the hardness and texture of the final food product. These phenomena will affect shrinkage, porosity, and glass transition temperature changes. The properties that will change during drying are color, taste/odor, nutritional value, and thermal character. The color changes during drying may be associated with water removal and the higher temperature that promotes heat-sensitive chemical reactions such as Maillard browning and oxidation. Applying the higher temperature will affect volatile compounds responsible for the taste and flavor of food. The losses of an initial volatile compound and the formation of the new volatile compound from enzymatic and non-enzymatic reactions during drying will affect the taste and flavor of the final dried product. Reducing moisture content and applying the higher temperature during drying will affect the nutritional values. Water-soluble vitamins and heat-sensitive bioactive compounds will decrease in the final dried product. The drying will reduce the final product's specific heat and thermal conductivity(Francisco *et al.*, 2013; Hardy and Jideani, 2017; Hamad *et al.*, 2020).

Berries such as blackberries, blueberries, strawberries, cranberries, and raspberries have received much attention due to their possible positive role in human health and disease prevention. Researchers have claimed that their polyphenol content, mainly anthocyanins, might be responsible for averting various diseases. The changes in berry fruit before and after spray drying and freeze drying are summaries in Table 1 from multiple sources (Flores *et al.*, 2014; Flores, Singh and Kong, 2014; Vaccinium and Compounds, 2016; Darniadi and Murray, 2017)

Table 1.The changes in berry fruit due to the drying process (Spray drying and Freeze drying)

Properties	**Before drying**	**After Drying**		**Comparative product from two drying methods**
		Spray Drying (SD)	**Freeze drying (FD)**	
Product	Berry Juice	Powders	Powders	Powders from FD have a color more bright than SD. The thermal properties of dried powder changed. Cp and K are less than berry juice
phase	Liguid / dispersion/ emulsion	Amorphous material powders)	Amorphous material (powders)	Powder particles from SD are denser. and more sphere, appearance more smooth, FD has the morphology irregular particles of larger size, articles resembled broken glass or flake-like structures

Moisture content (%)	80 – 98 %	0.5 – 4 %	2.5 – 5%	Commonly the moisture content powders from SD is significantly less than FD
Taste/Flavour	Juice taste	After rehydration, feel cooking taste	After rehydration, still juice taste	Dried berries from FD are a better taste due to the initial volatile compound responsible for taste.
Color	Original blueberry juice	Significantly different from Juice	Significantly different from Juice	Color from FD products is better than SD
Total phenolic compound		The losses are 76 – 78%	The losses are 60 - 62%	SD product has higher losses of total phenolic compound.
Anthocyanin content		The loss is 57 %	The losses are 35%	It indicates that heat destroys anthocyanin. Products from FD have higher color intensity

CONCLUSION

Drying is a method for preservative food material; this process will reduce water activity to less than 0.6. It will affect to inactive the growth of microorganisms. There are many desirable and undesirable changes in dried food products such as structure, color, taste, nutritional and thermal properties. Spray drying is the oldest drying method to get powders that products are easy to handle in storage and transportation. If the quality of the product is the primary concern, freeze-drying would be an option because this process does not apply heat suitable for the sensitive food material. Let's compare the result of berries powders product from these methods. The quality of the freeze-drying product is better in terms of taste/odor and color, and it has higher nutritional value and bioactive compounds. However, the morphology of the spray-dried berries powders is slightly better.

REFERENCES

Alexeenko, A Ganguly, S. . N. (2009) 'Computational Analysis of Fluid Dynamics in Pharmaceutical Freeze-Drying', *J. Pharmaceutical Sciences*, 98(9), pp. 3483–3494.

Chranioti, C. *et al.* (2016) 'Freeze-Dried Fennel Oleoresin Products Formed by Biopolymers: Storage Stability and Characterization', *Food and Bioprocess Technology*, 9(12), pp. 2002–2011. doi: 10.1007/s11947-016-1773-3.

Dantas, D. *et al.* (2018) 'Influence of spray drying conditions on the properties of avocado powder drink', *Food Chemistry*, 266(June), pp. 284–291. doi: 10.1016/j.foodchem.2018.06.016.

Darniadi, S. and Murray, B. S. (2017) 'Comparison of blueberry powder produced via foam-mat freeze-drying versus spray-drying : evaluation of foam and powder properties', (November). doi: 10.1002/jsfa.8685.

Eun, J. B. *et al.* (2020) 'A review of encapsulation of carotenoids using spray drying and freeze drying', *Critical Reviews in Food Science and Nutrition*, 60(21), pp. 3547–3572. doi: 10.1080/10408398.2019.1698511.

Fang, Z. and Bhandari, B. (2010) 'Encapsulation of polyphenols - A review', *Trends in Food Science and Technology*, 21(10), pp. 510–523. doi: 10.1016/j.tifs.2010.08.003.

Fellows P.J. (2009) *Food Processing Technology Principles and Practice*. 3rd edn. New Delhi: Woodhead Publishing Limited.

Flores, F. P. *et al.* (2014) 'Total phenolics content and antioxidant capacities of microencapsulated blueberry anthocyanins during in vitro digestion', *FOOD CHEMISTRY*, 153, pp. 272–278. doi: 10.1016/j.foodchem.2013.12.063.

Flores, F. P., Singh, R. K. and Kong, F. (2014) 'Physical and storage properties of spray-dried blueberry pomace extract with whey protein isolate as wall material', *Journal of Food Engineering*, 137, pp. 1–6. doi: 10.1016/j.jfoodeng.2014.03.034.

Francisco, E. *et al.* (2013) 'Comparison between freeze and spray drying to obtain powder Rubrivivax gelatinosus biomass', *Food Science Technology Champinas*, 33(1), pp. 47–51.

Hamad, A. *et al.* (2020) 'A novel approach to develop spray-dried encapsulated curcumin powder from oil-in-water emulsions stabilized by combined surfactants and chitosan', *Journal of Food Science*, 85(11), pp. 3874–3884. doi: 10.1111/1750-3841.15488.

Hardy, Z. and Jideani, V. A. (2017) 'Foam-mat drying technology: A review', *Critical Reviews in Food Science and Nutrition*, 57(12), pp. 2560–2572. doi: 10.1080/10408398.2015.1020359.

Ho, T. M. *et al.* (2019) 'Changes in physicochemical properties of spray-dried camel milk powder over accelerated storage', *Food Chemistry*, 295(May), pp. 224–233. doi: 10.1016/j.foodchem.2019.05.122.

Mohammed, N. K. *et al.* (2020) 'Spray Drying for the Encapsulation of Oils—A Review', *Molecules*, 25(17), pp. 1–16. doi: 10.3390/molecules25173873.

Nayak, B., Liu, R. H. and Tang, J. (2015) 'Effect of Processing on Phenolic Antioxidants of Fruits, Vegetables, and Grains—A Review', *Critical Reviews in Food Science and Nutrition*, 55(7), pp. 887–919. doi: 10.1080/10408398.2011.654142.

Normand, V. *et al.* (2013) 'Spray drying: Thermodynamics and Operating Conditions', *Carbohydrate Polymers*, 97(2), pp. 489–495. doi: 10.1016/j.carbpol.2013.04.096.

Ocampo-Salinas, I. O. *et al.* (2020) 'Development of wall material for the microencapsulation of natural vanilla extract by spray drying', *Cereal Chemistry*, 97(3), pp. 555–565. doi: 10.1002/cche.10269.

Ray, S., Raychaudhuri, U. and Chakraborty, R. (2016) 'An overview of encapsulation of active compounds used in food products by drying technology', *Food Bioscience*, 13, pp. 76–83. doi: 10.1016/j.fbio.2015.12.009.

Romano, N. *et al.* (2018) 'Physico-chemical and structural properties of crystalline inulin explain the stability of Lactobacillus plantarum during spray-drying and storage', *Food Research International*, 113(May), pp. 167–174. doi: 10.1016/j.foodres.2018.07.007.

Shishir, M. R. I. and Chen, W. (2017) 'Trends of spray drying: A critical review on drying of fruit and vegetable juices', *Trends in Food Science and Technology*, 65, pp. 49–67. doi: 10.1016/j.tifs.2017.05.006.

Vaccinium, B. and Compounds, P. (2016) 'Effect of Microencapsulation by Spray-Drying and Freeze-Drying Technique on the Antioxidant Properties of Blueberry', 66(1), pp. 11–16. doi: 10.1515/pjfns-2015-0015.