Section 5. Chemistry

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SPRAY DRIED FRUIT POWDER USING FRUIT JUICE CONCENTRATES

Abstract. The process of spray drying is regarded as a method that conventionally converts fruit juices like orange juices or concentrates to the powder fruit form. In this process, three main processes are involved in spray drying (Murungesan et al. [29]). These processes are:

- Atomization
- Droplet –hot air contact and evaporation of moisture.
- Separation of products that have dried from the exit air

Feed

- Orange concentrates and lemon concentrates with water (slurry mixture)

Output

- Orange fruit powder
- Lemon fruit powder

In this study's scope, we investigated the procedures within the fruit drying spray responsible for yielding fruit powders using orange and lemon fruit concentrates. The production of fruit powder from fruit condenses calls for the use of drying aids, which function as an agent for reducing stickiness concerns that arise during the fruit spray drying technique. This paper illustrates the process of fruit spray drying with orange and lemon fruit concentrates and how the fruit powder form can be used in a production application (Boonyai et al. [35]).

The concentrated orange and lemon juice are spray-dried using air that is dehumidified as a medium for drying, and the agent used for drying is maltodextrin. For the spray drying process, the piloting-scale dryer is used.

Keywords: spray drying, fruit powders, fruit concentrates, processing of lemon and orange juices

Introduction

A spray drying process is an operational unit such that liquid products (orange and lemon fruit concentrates) go through the process of atomization in a stream of hot gas in order to get instant fruit powder. The fruit spray drying method is developed in relation to the production of dried fruit powders. The initial solution (slurry) used as a feed in the spray drying activity can be in a solution form that is a suspension emulsion (Gharssallaoui et al. [2]). The product is turned into powder, granules, and agglomerates. These forms depend on chemical features, the feed's physical feature, the feed and the design of the dryer, and how it is operated (Filkova et al., [4]). The requirements of the spray dry, such as the drying agent concentration that is used, the temperature of the inlet, the flowing rate of the feed, and the features of the feed, all affect the fruits that are spray dried as well as the characteristics of the pulp powder that is produced during the process (Chegini et al. [8]). The different ways the spray dryer displays itself include concurrent, counter current and flow with the mixture. Spray dryers that are concurrent are commonly used. In concurrent, there is the travel of the droplets of the feed-in in a direction that is the same as the flow of the gas used for drying (Zbincinski et al., 2002).

Steps for spray drying process

Atomization Step

This is among the essential steps in the fruit spray drying activity; this process enhances the conversion of fluid fruit into tiny droplets (Murungesan et al., [18]). Due to the reduction in particle size and particle dispersion in the gas used for drying, an exponential increment of the particle area is subsequently done, enhancing feed drying quickly. When the droplet size is tiny, and the feed fluid distribution is minimal, there is moisture in the material without the material's integrity being affected. Because the droplet size is small, atomization is performed by atomizers, commonly classed as rotary sprayers, pressure nozzles, compressor nozzles, and supersonic nozzles. The choice of atomizers is determined by the specific feed selected to be dried, the ultimate qualities of the intended feed, and the particle shape.

In this case, we chose the orange and lemon concentrates to be used as the feed-in fruit spray drying.

Droplet-air contact and Evaporation of Moisture

Generally, the air of the atmosphere is used to dry in the spray drying process. During the spray drying activity, the air from the atmosphere undergoes the process of filtration through the system used for filtering. Then it is preheated subsequence per the parameters of opera ration. At times, nitrogen gas and other inert gases are used with the dependence on the feed undergoing the drying process and the instability and sensitivity of the feed concerning oxygen (Sollohub and Cal [25]). The process of the feed droplets being dried after contact with the medium for drying in the spray drying activity is the effect of simultaneous heat and the transfer of mass. The drying medium heat is transferred to the droplets through the convection method, and then the conversion of the heat latent during the process of evaporating the moisture content of the droplet. The heart rate and heat transfer depend on the droplet's diameter, relative velocity, and air velocity (Orsat and Mungesan [29]). The starting time for drying in the spray drying process starts once there is contact between the droplet and the medium for drying. This process is accompanied by the rate of a falling duration, where the drying rate starts decreasing, and the time ends immediately when the droplets can reach the critical moisture content (Filkova et al. [4]).

Separation of the substance that is dried from the exit air

The cyclone, which is positioned outside the dryer and serves the purpose of reducing the amount of product lost to the environment, is used in the separation process. The denser particles are regained at the drying chamber's base, while the finer particles are passed via the cyclone to undergo separation from the humidified exit air (Gharsallaouii et al. [4]).

The types of fruit powders that can be made from the orange and lemon concentrate

The lemon and orange concentrates can be spray dried to create fruit powder. These fruit concentrates are typically pasteurized; mixing with the carriers takes place to ensure that they are stably dry for them to be fed to the spray drying machine. The mixture usually undergoes a pumping process through the nozzle and then passes into the chamber that has been heated with the hot air vortex. As a result, the water in the mixture is evaporated then the fruit powder is collected at the outlet. The following are some fruit powders that can be formed from the orange and lemon juice concentrate depending on the manufacturing feasibility, cost, and the final product quality required (Boonyai et al. [35]).

Roller fruit powder/belt dried fruit powder

This type of fruit powder is commonly primary. For this type of powder to be achieved, there is a long set of rollers in which fruits are passed through a chamber that has been heated in the roller drier or passed into a long belt conveyor through a chamber that is heated. The higher temperature in the chambers can remove as much water as possible from the fruits, and then the fruits that have been dehydrated are then milled, ground, and then crushed into the powder form that is fine.

It allows specific formulations. – These are relations to the properties of the powder, texture, and flavors. This process is also favorable for drying in an atmosphere with less oxygen because it avoids oxidation.

Disadvantages of roller fruit powder process.

The drum drying is limited to the liquids that are highly viscous or pastes. Therefore, this process is only suitable for specific product types.

Vacuum dried fruit powder.

The way is a specialized process of producing the fruit powder, and in this case, there is avoidance of high temperature (Murungesan et al. [18]). The fruits are dried just like the roller fruit powder, but the batch process is sealed in the vacuum chamber. The vacuum drops the boiling point of water to 30 degrees by illustrating that the fruits require low temperatures for water to be evaporated from the fruits. This process is suitable for fruits that are sensitively suited to temperature even though the process is expensive; it is minimally harsh on the fruits, preserving the flavor of the fruit powder.

Advantages of vacuum fruit powder process.

It lengthens the storage time of the fruit powders while their original flavor is maintained.

The vacuum-manufactured fruit powders do not change color and do not develop foul odors (Murungesan et al. [18]).

This process can enable a wide variety of new products throughout the year, even during the off-season of used fruit.

This process also enhances the prevention of unnecessary wastage of fruit powders.

A vacuum dryer provides a large surface for transferring heat throughout the body; therefore, there is faster drying action.

There is supplied hot water to the dryer that facilitates the process of drying at the temperature that is desired.

The electrically-heated hollow shelves are used.

The handling of materials in this process is effortless.

Disadvantages of vacuum-dried fruit powder process.

The dryer is a type of process based on a batch.

The efficiency of the process is low.

The process is costly.

The cost of labor in this process is high.

The process needs to be highly maintained.

The process can be subjected to the danger of overheating because of the vacuum.

I have freeze-dried fruit powder.

The process of freeze-drying is a batch process that occurs in a sealed chamber. Freezing of the fruits is done, and then there is a gradual reduction in the pressure, which makes the water in the fruit directly jump from the phase of ice straight to the phase of vapor. This process can be classified as a sublimation process. The water flavor in the fruit leaves freely from the fruit. This process highly results in hydrated fruit with fully maintained integrity. After this is done, the fruit can be milled and crushed into the required powder. Because this process is expensive, it results in desired results, producing highly priceable fruit powder, arguably the most preserved (Murungesan et al. [29]).

Advantages of freeze-drying

The fruit powders produced through this process have nutritional value and are synthetically free from artificial and highly processed materials.

The fruit powders from this process are close to their new form. This means that when the fruit-dried powders have retained their nutritional values, they support the desire of the consumer's nutrition from the whole fruit.

Customization advantage

This means that the fruit powders from the process mentioned earlier can customize the project goals and the unique needs.

Application in varieties

The capabilities of blending and customization allow the fruit processors to incorporate orange and lemon fruits into different large varieties of applications.

I have a prolonged shelf life. -The shelf life of any fruit powder depends on the moisture content of the fruit concentrates. Bacterial growth is potentially removed when water is removed from the fruit powder. The fruit powder's moisture differs from different fruits, but the average content of the fruit powder's moisture is about 3%. The average shelf life of a fruit powder that has been freeze-dried depends on the packaging of the fruit powders, the storage temperature, and the fruit powder production fruit.

Disadvantages of freeze-drying fruit powder

There is a requirement for water to reconstitute the process.

The process is slow and has an average cycle of 24+ hours.

There is a dislike for the dry and Styrofoam texture of the fruit powders produced through this process.

Air-tight containers are required for a longer time of storage.

There is no space saving because the fruit's cellular structure is mostly retained.

Regular dehydration of the fruit powders is better.

It has a high fruit powder production cost.

Spray Dryer Parameters

Natural hygroscopes and property of thermoplasticity of the fruit juice is the most common issue in transporting and handling the powdered juice fruit produced from the fruit dryer. The pilot plant test is usually used for the performance specification to be met. Examples of these specifications are: the conditions used in optimization, flow current of the type of the dryer, time residence, air humidity, and the ancillary equipment (Adhikari and Bhabdari [5]).

These specifications are required to complete the drying process without influencing the fruit powder's quality. It also prevents the formation of unacceptable wall deposits on the semi-dried product. The spray dryer used in the industrial orange and lemon fruit drying to produce the fruit powders should be designed using information that is accurate according to the behavior of the agent used for dying. The above specification should be analyzed through a laboratory test of the spray dryer.

Two complicated challenges arise during the production of orange and lemon fruit powders. There are two significant problems to be solved: one is the powder's stickiness and its difficulty in handling, and the other is caused by the features of the citrus concentrates that impact the manufacturing of the powdered orange and lemon fruit (Boonyai et al. [35]). For the hygroscopic decrease of citrus fruit juice, drying agents are needed. It is possible to speed up the drying process by modifying the physical characteristics of the materials employed as drying agents. Maltodextrin is one of the finest drying agents for manufacturing fruit powders utilizing orange and lemon concentrates. Other drying agents include corn syrup, natural gum, sucrose, and others. The dryer's walls don't attach to the particles while using these drying ingredients, which boosts power generation.

When fruit powder production using orange and lemon concentrate is not done using the drying materials, there is a limited production of the fruit powders. Therefore, in addition to the production of powder, the fruit spray dryer's qualities depend on the operation variables.

The optimum operating conditions are obtained when the operating variables are studied and determined in producing fruit powders using the orange and lemon concentrates.

The following results were obtained in the test for the drying without additive material and for drying using the agent drying materials.

Drying without the addition of drying agents

The design factors include the flow of air current, condition operation of the dryer, orange and lemon juice characteristics, time of residence, the drying agent suitable for the process, and temperature of the point of stickiness (Boonyai et al. [35]). The airflow currents suitable for fruit drying, in this case, are concurrent due to the low heat damage. For undamaged concentrates and the viscosity of orange and lemon juice to be suitable, the feed's maximum temperature should be around 60 degrees Celsius. The temperature for atomization should be very hard at a less temperature of 5 degrees Celsius. The most suitable feed concentrate temperature for the orange and lemon concentrates should be between 20–35 degrees Celsius. When the orange and lemon fruit juice concentrates were produced without drying agent materials, there was no production of the orange and the lemon fruit powder. The feed materials get stacked on the dryer's walls and the cyclone. As the process continued, a hard film of glass was shaped on the wall. During the changing of the conditions for operating, like the change in the inlet air temperature and the rate of feed flow, there was yield in the powder but no improvement (Adhikari and Bhabdari [5]).

When drying agent materials like sucrose and fructose are used, the orange and lemon fruit concentrate the hygroscopic nature and thermoplastic nature, so the fruit dried powder and the particles that have been dehydrated do not stick on the walls of the dryer.

When the orange and lemon have irregular structures, water can act as a plasticizer and enhance the chaining of the irregular structure of the lemon and orange materials. The little water applied enhances the reduction of the transition temperature of the glass until it reduces to temperatures below the home temperature.

Drying through the use of agent drying materials

When the experiments are conducted using the maltodextrin dying agent in the orange and lemon concentrates, the yield of the powders increases. When the conditions of the operating dryer are measured, the results show that the yield of the fruit juice powders increased from 18–35 percent, and deposition on the wall still occurred in the range of 67–82 percent. The cyclone and chamber particles accumulated, and the physical powder properties are measured. The density and bulkiness of the powder showed a decrease (Murungesan et al. [29]).

Time of Residence- the residence time is sufficiently required to facilitate the necessary permission to complete the drying process. The spray dryer residence time is essential in drying to prevent the under-sizing and over-sizing of the chamber used for the drying process.

The temperature of the sticky point – The temperature at which the amount of soft powder put on the plate sticks on the wall of the plate.

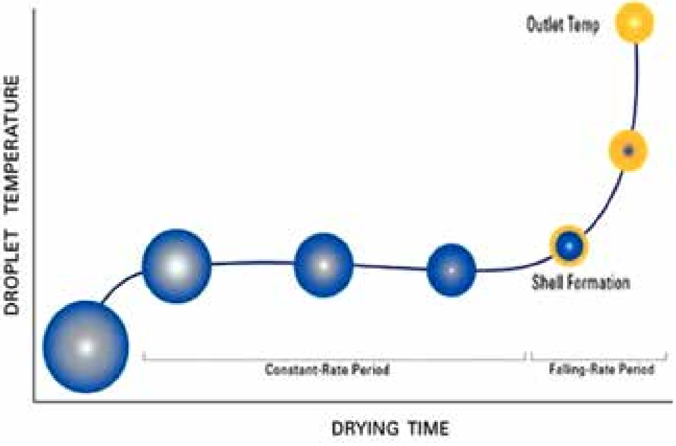

Figure 1. Lewandowski et al., 2019

Spray drying of lemon and orange juice concentrates

In the drying technique, the spray drying process is applicable in producing the fruit juice powder. In fruit juice spray drying, this process is essential because it aids in handling the demand in the market through the years. When there is the presence of high content of moisture in the orange and lemon concentrates, there will be a high activity of water in the feed that will cause a loss of fruit quality that leads to increased enzymatic activities and growth of micro bacteria. As a result, the reduction of water content in the feed materials, which is **the slurry mixture**, and the activities of water in lemon and orange concentrates lead to the production of the desired quality dried fruit powder. **When the feed slurry mixture** consists of fruit concentrate and water used to produce fruit dried powder, the fruits used as concentrates can be divided into two main groups. These include the sticky and non-sticky groups.

The non-stick fruits are easily spray dried through a designed simple dryer, and the powder that is finally produced remains flowing freely (Tan et al. [24]). When the fruit is sticky, issues arise in the process of drying when using the standard conditions. The sticking fruits get stacked on the walls of the dryer, or they generally undergo agglomeration in the chamber used for drying. This leads to the conferment of the systems to the problems with the operation and production of low-quality powder products. Consider the diagram below.

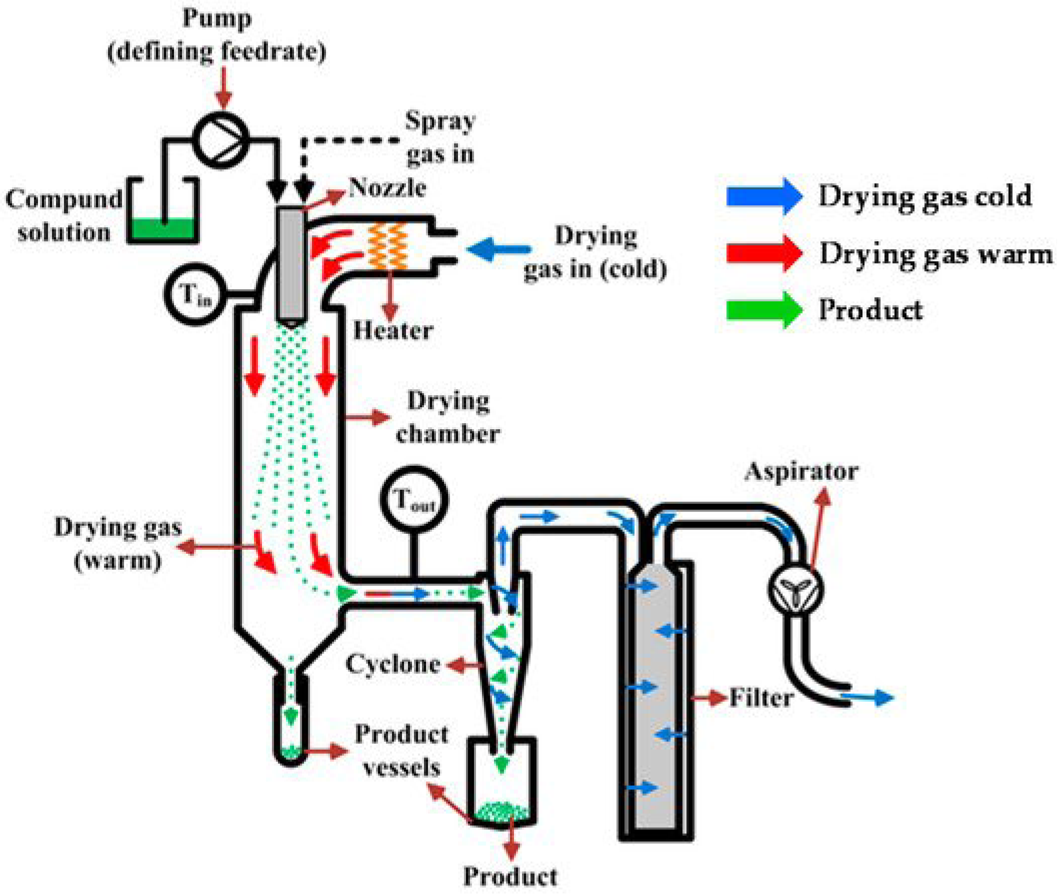

Figure 2. Buchi Labortechnik AG, 2019

The cohesion and adhesion characteristics of the powder's stickiness are illustrated in the form of stickiness between the particle-particle and the particle's stickiness on the dryer's surfaces (Bahu et al. [6]). The measure at which the forces hold the particles together to their internal property is cohesion which causes the lump to form in the bed powder. Therefore, the forces needed for the powder's agglomerates to be broken must be larger than the force of cohesion (Mani et al. [28]).

The force of adhesion has interfacial features, which is the tendency of particle powder to attach to the surfaces of the spray dryer used for drying. The cohesion and adhesion forces are designed as critical factors of spray drying dryers and drying process conditions. The stickiness associated with the spray drying technique can both be present during the spray drying of sugar-rich fruits. In this scenario, the spray-dried powders are made from orange juice concentrates, and orange juices, by definition, include some sugar. As a result, when performing fruit spray drying of orange juice concentrates, expect both stuckness and stickiness to occur (Adhikari and Bhabdari [5]).

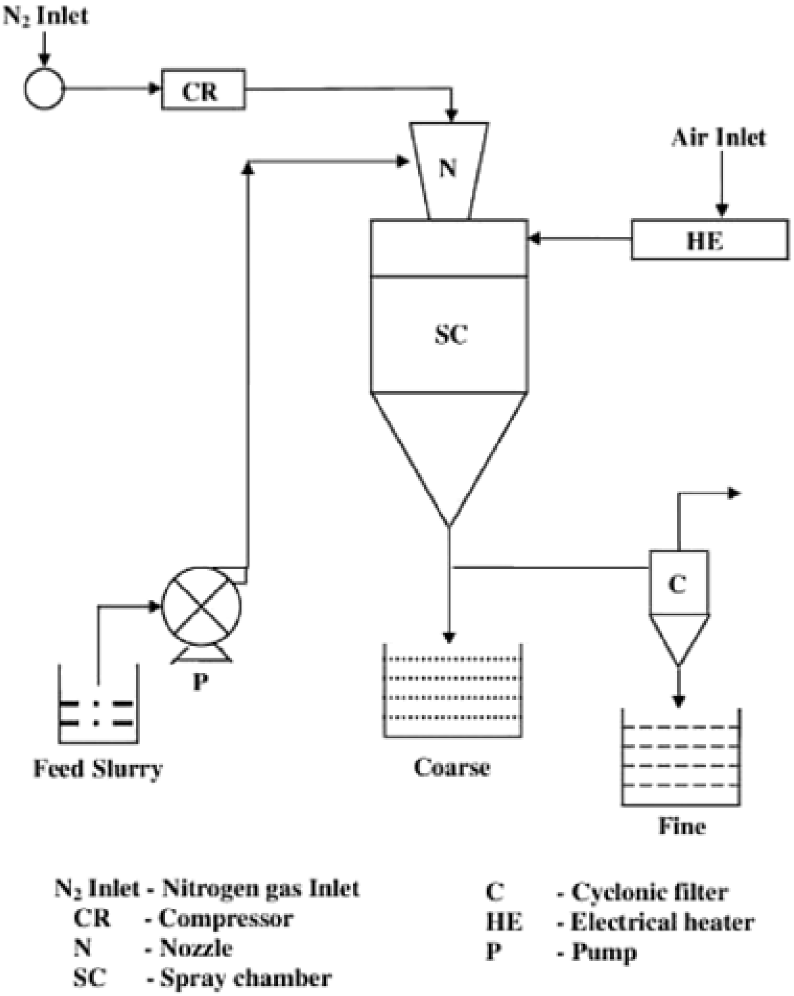

Figure 3. Flow diagrams for the process of fruit spray drying using lemon and orange fruit concentrates

The stickiness that occurs due to antiparticle is cohesion and is brought by the formation of immobile liquid bridges, the intermolecular forces caused by the interlocking mechanical forces and forces of electrostatic and bridges of solids (Boonyai et al. [35]). The adhesion of particle powders with the wall chambers of the dyer is one of the most causative factors for the loss of materials in the process of fruit drying of the sugar-rich fruits and acid-rich fruits. Then the powder quality is decreased when retaining on the dryer walls occurs for a long time (Maa et al. [37]). In this case, we are using the orange and lemon, which are sugar-rich and acid-rich materials.

The process of spray drying orange juice and lemon juice, since they are sugar and acid-rich materials, has witnessed some difficulties due to their lower molecular weights of the sugars and organic acids. The high hygroscopic nature, thermoplasticity, and low temperature of glass are the features that lead to the powders' stickiness on the dryer's wall.

At a temperature used for spray drying $T_g + 20$ degrees Celsius, the components can form soft particles, with the surfaces being sticky, leading to the stickiness of the powder and the formation of paste structures rather than powder forms (Jing et al. [16]). The molecules have high molecular mobility due to the molecule's low transition glass temperatures, leading to the problem of stickiness and the prevailing average temperatures in the dryer.

The temperature of the glass transition parameter is the most essential and suitable parameter used in assessing the lemon fruit juice and orange fruit juice materials used in spray drying (Langrish et al. [32]). To minimize the thickness problem in spraying drying, drying agent materials with high molecular weights are used in the feed materials before atomization takes place to ensure increased glass transition temperatures (Cabral et al. [1]).

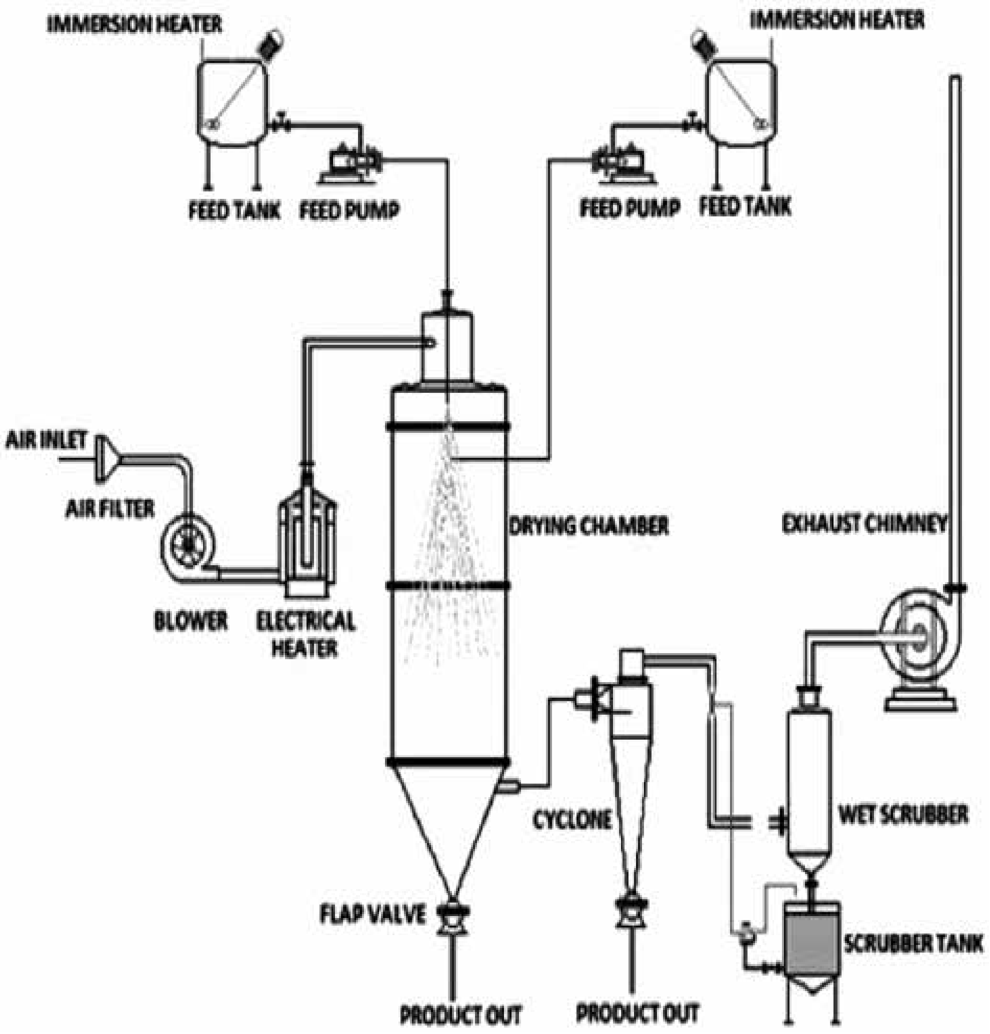

Figure 4.

Sourced from (Bhandari, Data, and Howes, 1997)

The drying agent materials are different like maltodextrin, Arabic gum, starches that are modified, and proteins applied in the process of spray drying to ensure minimization of the stickiness of the powder that occurs in the walls of the dryer (Caliskan and Drum [21]). The maltodextrin product consists of starch that has been hydrolyzed and entailing the D-glucose units linked by (1→4) glycosidic bonds. Maltodextrin is described using its equivalence of dextrose (D. E.), which is averagely related to the inverse of the molecular weight. Maltodextrin is considered because its cost is low, and it is helpful in fruit drying using a spray dryer. At the same time, Gum Arabic is an exudate of the acacia tree, obtained from the natural plant. Moreover, it consists of structures that are highly ramified in hetero-polysaccharide. The Arabic gum is the only gum that can be used in fruit juice products with high solubility and low viscosities in an aqueous solution. As a result, the spray drying process is made more accessible (Bemiller and Whistler [28]). Due to the increased overall value of T_G in the feed concentrates, powder stickiness is decreased by using maltodextrin, Arabic gum, and starches modified as materials used for dying during the spray drying process. When proteins are used as drying agent materials, they help minimize the stickiness problem through the property's modification of the surface of the droplets and particles that have been atomized while considering the forming of film features and protein surface activities (Adhikari et al. [26]). Due to the forming of film feature and surface activities of the protein, there is the migration of proteins to the surface of the air-water interface of particles that have undergone atomization of feed droplets hence the formation of a film protein which undergoes conversion into skin glass with the transition high glass temperature. This means that when there is subjection to hot and dry air. The skin that results can overcome the coalescence of the droplets and interaction of sticky particles in the chamber used for dying (Jayasundera et al. [26]).

How conditions of spray drying process affect physicochemical, microstructural, and antioxidant properties of resulting fruit powder

The spray-dried fruit powder characteristics rely on the spray drying conditions such as the drying aid concentration, the temperature of the inlet, the rate of the feed flow, and the feed characteristics (Chegini et al. [17]). According to Nanda and Suhag, when they did their study on the spray drying process to produce lemon and orange fruit powder using the whey concentrate protein as a drying agent, the resulting process showed that when the air inlet temperature is increased, the bulk density is reduced, antioxidant activities are also reduced. However, there is an increase in the powder's hygroscope. When the concentrations of whey protein are increased, the bulk density increases while the powder hygroscope decreases. The increased whey protein concentration positively influences the activities of antioxidants and the vitamin C retention in the orange and lemon fruit powder produced. This shows the relationship between encapsulation superiority features of whey concentration protein and the prevention of damage caused due to oxidation.

Bandari and Fang (2012) also studied the spray drying process of orange fruit powder using orange fruit concentrates, whey protein isolate, and maltodextrin as drying agent materials. There was no recovery of fruit powder when the orange juice concentrates were spray-dried without spray drying agent materials. A protein of a small amount was efficient for the recovery of 50% powder for the orange fruit juice to be spray-dried, while maltodextrin in more significant amounts (around 30%) was required for the same purpose. There was a disclosure of the preferential protein migration to the droplet/particles surfaces by the authors, and the formation of a layer of glass during the process of spray drying resulted in the decreased adhesive property between the particles and the wall of the dryer during the fruit spray drying process of orange juice fruit concentrate. The ability of maltodextrin to reduce stickiness is because of the orange fruit powder's increased glass transition temperature. The authors who conducted the study reported that there was a low activity of water on the powder, about 5%, and the addition of whey protein at a percentage of 1 because whey protein has a level that has relation to the holding capacity of water in the protein. The graph below shows the relationship between moisture content and temperature in the process.

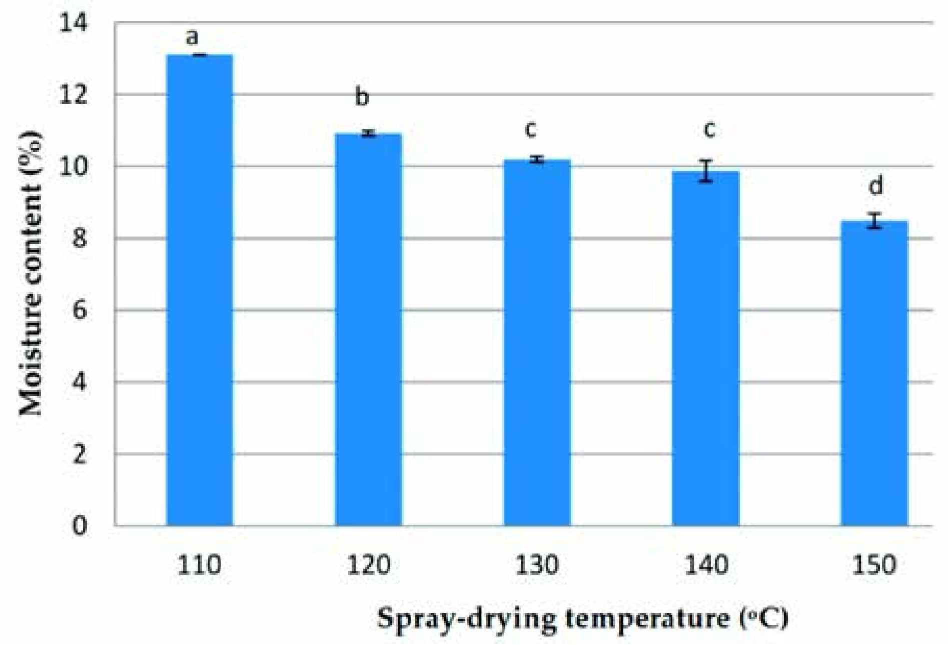

Figure 5.

Tonon et al. [15] researched the property of physicochemical in the spray drying of orange and lemon that is affected by the conditions of spray drying. The resulting solution showed that the yield in the powder production was influenced positively by the temperature of the inlet air. There was a negative influence on the feed flow rate related directly to the transfer of mass and heat. The addition of a concentrated form of drying agent (maltodextrin) reduced the yield of the process due to the higher viscosity of the feed solution. Flow rate and maltodextrin concentration had a favorable effect on the powder's water content, which was lowered due to increasing air temperature. The powder hygroscopic was reduced when maltodextrin content and feed flow rate were raised. According to powder morphology, the intake air temperature was also lowered. The higher inlet air temperature leads to a greater number of particles with smooth surfaces and big sizes due to the rapid drying rate of the drying agents utilized in this experiment.

Spray-dried orange juice powder's physicochemical properties were examined by Mishra et al. [16]; they used maltodextrin as a drying agent and inlet air temperature as a control. When the air input temperature and maltodextrin levels were varied, both water content and powder hygroscope were impacted. When maltodextrin content and the drying temperature are increased, the fruit powder loses some of its radical scavenging ability. The effect of drying rate and maltodextrin percentage on orange fruit powder's total phenolic content was shown.

Chegani et al. (2005) also conducted a study on the influence of the flow rate of the feed, the speed of atomization, and the air temperature of the inlet properties of the orange spray-dried powder. Results illustrate that an increase in the air inlet's temperature increased the particle's size; hence, the atomization speed increased.

Conclusion

The spray drying process is a technology that is important in producing fruit powder. Even though this technological process is good, it is associated with the problem of the stickiness of the powder juice that is occurring at a prevailing average temperature of the spray dryers. This problem is reduced by the use of the molecular weight of drying agents that is higher. The spray-dried fruit powder characteristics are influenced by the spray drying conditions, such as the drying agent material used, the temperature of the inlet, the rate of the feed flow, and the characteristics of the feed used. There are several ways of drying fruit powder. There is a way to dry them without using drying agents, and there is also drying by using a drying agent. There is also spray drying, which applies to oranges and lemons juice concentrates. It involves three steps: automation followed by droplet air contact, evaporation of moisture, and separation of dry products from exit air. In this method, spray drying affects the physicochemical, microstructural, and antioxidant properties of a fruit creating the fruit powder. When drying without using drying agents, water can act as a plasticizer and enhance the chaining of the irregular structure of the lemon and orange materials. The little water applied improves the reduction of the transition temperature of the glass until it reduces to temperatures below the home temperature. There are several types of fruit powders roller fruit powder, vacuum dried fruit powder, and freeze-dried fruit powder. All these forms have their advantages and disadvantages. For example, one disadvantage of freeze-drying, one requires water to complete the process. On the other hand, vacuum drying is advantageous because it can lengthen the storage time of the fruit powders while still maintaining the original flavor.

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