# Spray Drying: A Novel Processing Technique

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## Introduction

Drying is one of permanent method of preservation for food items among different methods of drying. Spray drying is widely used drying technique for conversion of a suspension or solution into a dry form. In this technique suspension or solution feed is atomized and the droplet formed comes into contact with a hot gas. In spray drying, the inlet air temperature typically ranges from 150 to 250$^0$C, with outlet temperatures ranging from 50 to 80$^0$C. (Afoakwah *et al.,* 2012).

The process of simultaneously atomizing and desiccating fluid and solid substances, and its application to the purpose of the exhaustion of moisture from such substances, and for the prevention of destructive chemical change. It is the transformation of feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium. (Hui *et al.,* 2008)

Spray drying is the continuous transformation of feed from a fluid state into dried particulate form by spraying the feed into a hot drying medium. The feed may be solution, slurry, emulsion, gel or paste, provided it is pumpable and capable of being atomized. It involves bringing together a highly dispersed liquid and a sufficient volume of hot air to produce evaporation and

drying of liquid droplets. The air supplies the heat for evaporation and conveys the dried product to the collector; the air is then exhausted with the moisture.

The production of particles from the process of spraying has gained much attention in recent years. These efforts have resulted in spray technology being applied to the manufacture of particles to generate products ranging from pharmaceutical direct compression excipients and / or granulations to microencapsulated flavours.

The two main spray techniques are spray drying & spray congealing. The action in spray drying is primarily that of evaporation, whereas in spray congealing it is that of a phase change from a liquid to a solid. The two processes are similar, except for energy flow. In the case of spray drying, energy is applied to the droplet, forcing evaporation of the medium resulting in both energy and mass transfer through the droplet. In spray congealing, energy only is removed from the droplet, forcing the melted to solidify.

Spray drying is the most widely used industrial process involving particle formation and drying. It is highly suited for the continuous production of dry solids in either powder, granulate or agglomerate form from liquid feedstocks as solutions, emulsions and pumpable suspensions. Therefore, spray drying is an ideal process where the end-product must comply with precise quality standards regarding particle size distribution, residual moisture content, bulk density, and particle shape.

## Spray drying principle

Spray drying is a unit operation by which a liquid product is atomized in a hot gas current to instantaneously obtain a powder. The gas generally used is air or more rarely an inert gas.

## Basic steps of spray drying

There are three fundamental steps involved in spray drying.

1) Atomization of a liquid feed into fine droplets.

2) Mixing of these spray droplets with a heated gas stream, allowing the liquid to evaporate and leave dried solids.

3) Dried powder is separated from the gas stream and collected.

Spray drying involves the atomization of a liquid feedstock into a spray of droplets and contacting the droplets with hot air in a drying chamber. The sprays are produces by either rotary (wheel) or nozzle atomizers. Evaporation of moisture from the droplets and formation of dry particles proceed under controlled temperature and airflow conditions. Powder is discharged continuously from the drying chamber. Operating conditions and dryer design are selected according to the drying characteristics of the product and powder specification.

## Atomization

The atomizing device, which forms the spray, is the ´heart´ of the spray drying process Atomizer: Equipment that breaks bulk liquid into small droplets, forming a spray.

## Primary functions of atomization are:

a. A high surface to mass ratio resulting in high evaporation rates,
b. Production of particles of the desired shape, size and density.

The aim of atomizing the concentrate is to provide a very large surface, from which the evaporation can take place. The smaller droplets, the bigger surface, the easier evaporation, and a better thermal efficiency of the dryer are obtained. The ideal from a drying point of view would be a spray of drops of same size, which would mean that the drying time for all particles would be the same for obtaining equal moisture content.

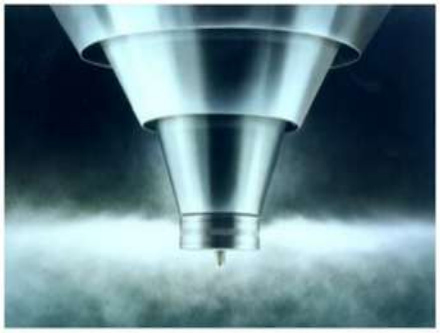
In order to produce top-quality products in the most economical manner, it is crucial to select the right atomizer. Three basic types of atomizers are used commercially:

a. Rotary atomizer (atomization by centrifugal energy)

b. Pressure nozzle (atomization by pressure energy)

c. Two-fluid nozzle (atomization by kinetic energy)

**Rotary atomizers: Atomization by centrifugal energy**



Rotary atomizer uses the energy of a high speed-rotating wheel to divide bulk liquid into droplets. Feedstock is introduced at the center of the wheel, flows over the surface to the periphery and disintegrates into droplets when it leaves the wheel.

Advantages of rotary atomizers:

- Great flexibility & ease of operation.
- Low pressure feed system.
- No blockage problems.
- Handling of abrasive feeds.
- Ease of droplet size control through wheel speed adjustment.

Disadvantages of rotary atomizers:

- Produce large quantities of fine particles, which can result in pollution control problems.
- High capital cost.
- Very expensive to maintain.
- Cannot be used in horizontal dryers.
- Difficult to use with highly viscous materials.

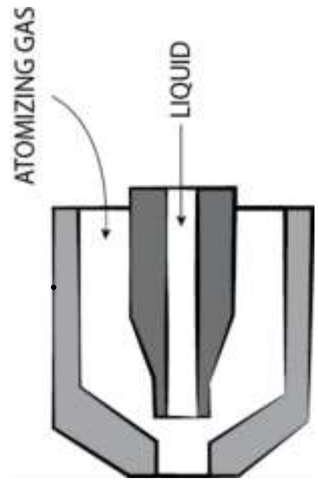
Because of the problems and costs associated with rotary atomizers, there is interest within segments of the spray dry industry in replacing rotary atomizers with spray nozzles.

**Pressure nozzles: Atomization by pressure energy**

Pressure nozzle is the most commonly used atomizer for spray drying. Nozzles generally produce coarse, free flowing powders than rotary atomizers. Pressure nozzles used in spray drying are called "vortex" nozzles because they contain features that cause the liquid passing through them to rotate. The rotating fluid allows the nozzle to convert the potential energy of liquid under pressure into kinetic energy at the orifice by forming a thin, high-speed film at the exit of the nozzle. As the unstable film leaves the nozzle, it disintegrates, forming first ligaments and then droplets. Pressure nozzles can be used over a large range of flow rates, and can be combined in multiple-nozzle installations to give them a great amount of flow rate and particle size flexibility. The range of operating pressure range for pressure nozzles used in spray drying is from about 250 PSI (17.4 bar) to about 10,000 PSI (690 bar).

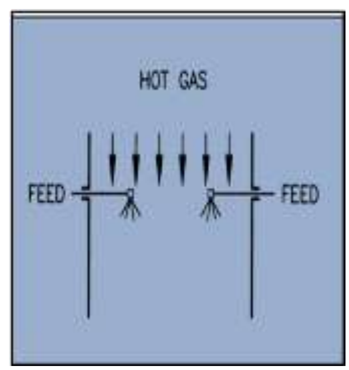
**Two-fluid or Pneumatic nozzles: Atomization by kinetic energy**

Liquid feedstock and compressed air (or steam) are combined in a two-fluid Nozzle. The design utilizes the energy of compressed gas to atomize the liquid. Two advantages of the two-fluid nozzle are its ability to produce very fine particles and to atomize highly viscous feeds. However, two-fluid nozzles are expensive to operate because of the high cost of compressed air. Two fluid nozzles are often used in laboratory and pilot plant spray dry applications because of their ability to produce a wide range of flow rates and droplet sizes. The range of operating pressure range for pressure nozzles used in spray drying is from about 250 PSI (17.4 bar) to about 10,000 PSI (690 bar).

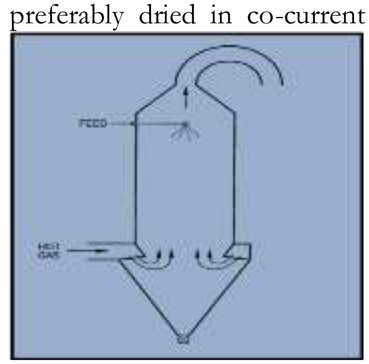



**Types of spray dryer systems : On the basis of the type of flow**

**Co-current flow dryer:** In the co-current flow dryer, the spray is directed into the hot air entering the dryer and both pass through the chamber in the same direction. Spray evaporation is rapid, and the temperature of the drying air is quickly reduced by the vaporization of water. The product does not suffer from heat degradation since once the moisture content reaches the target level, the temperature of the particle does not increase greatly because the surrounding air is now much cooler. Dairy and other heat-sensitive food products are preferably dried in co-current dryers.

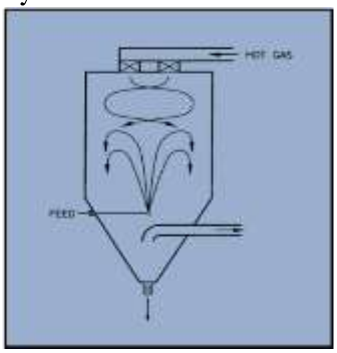



**Counter-current flow dryer:** In this spray dryer the air is introduced at opposite ends of the dryer, with the atomizer positioned at the top and the air entering at the bottom. A counter-current

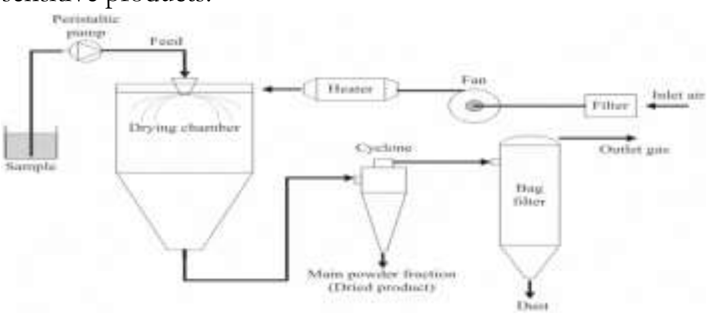


dryer offers more rapid evaporation and higher energy efficiency than a co-current design. Because the driest particles are in contact with hottest air, this design is not suitable for heat-sensitive products. Counter-current dryers normally use nozzles for atomization because the energy of the spray can be directed against the air movement. Soaps and detergents are commonly dried in counter-current dryers.

**Mixed flow dryer**




Dryers of this type combine both co-current and counter current flow. In a mixed flow dryer, the air enters at the top and the atomizer is located at the bottom. Like the counter-current design, a mixed flow dryer exposes the driest particles to the hottest air, so this design is not used with heat-sensitive products.




**A schematic diagram of the Spray Drier**

**Preparation of Feed Solution:** The liquid to be dried (a solution, suspension, or slurry) is prepared in a feed tank. The feed must be pumpable and sometimes pre-filtered or heated.

**Atomization:** The feed is pumped into an atomizer, which converts the liquid into tiny droplets. Atomizers can be: Rotary disk atomizers, High-pressure nozzles, Two-fluid nozzles. The size of droplets affects the drying rate and final powder properties.

Drying in the Chamber Hot air (drying gas) enters the drying chamber, either co-current (same direction) or counter-current (opposite direction) to the droplet flow. As the droplets fall through the hot air: Moisture evaporates rapidly. The droplets become dry particles before reaching the bottom.

**Separation of Particles:** The air-particle mixture exits the chamber and enters a cyclone separator. Using centrifugal force, the cyclone separates fine powder from moist exhaust air.

**Powder Collection:** The dry powder is collected at the bottom of the cyclone or in a separate powder collector. Collected powder is often cooled and packaged for use.

**Exhaust Air Handling:** Moist air is vented or sent through filters or scrubbers to remove dust before release.

**Factors influence the properties of product**

- Inlet temperature- Normally, the temperature used for food powder is 150-220$^0$C.
- Feed flow rate-The higher feed flow rate showed a negative effect on process yield.
- Atomizer speed- At higher atomizer speed, the smaller droplets were produced and more moisture evaporated.
- Types of carrier agent– Maltodextrin is considered as best carrier agent.

**Spray dryer advantages, disadvantages, applications**

**Advantages of spray drying:**

- Low water activity and moisture with long shelf life
- Reduce the weight
- Reduce packaging and transportation cost
- Storage require less space
- Faster dehydration method
- It can be used to both heat-resistant and heat sensitive products. (less contact with heat)
- It retain the colour, flavour, aroma and nutritional value of product

**Disadvantages of spray drying:**

- The equipment is very bulky and with the ancillary equipment is expensive.
- The overall thermal efficiency is low, as the large volumes of heated air pass through the chamber without contacting a particle, thus not contributing directly to the drying.

**Applications**

**Food applications**

- Milk powder: Skim and whole milk
- Whey powder: Ordinary, sweet, acid
- Infant food, Coffee/Tea whitener
- Casein/caseinates, Ice – cream mix
- Encapsulated flavours, bioactive compounds and nutraceuticals

**Non-food applications**

- Detergents, soaps and surface active agents
- Pesticides, herbicides, fungicides and insecticides
- Dyestuffs, pigments, fertilizers, Antibiotics, vaccines, vitamins, yeast and tannin products
- Enzymes, hormones, and amino acids
- Aerosol formulation, Ceramic materials

## Conclusion

- Spray drying remains as one of the best methods for preserving bioactive components in horticulture produce.
- It is a powerful technique that converts juices into stable powders, helping reduce spoilage, add value and make seasonal commodity available year-round, while preserving their nutrients and flavour.
- Powders either stand alone as food product or as an ingredient in another product and thus help in promoting health and nutrition.
- Powders are best way of preserving the bioactive compounds for long term.
- Spray drying can be advantageous route to pharmaceutical manufacture. In the production of powders for direct compression tableting, this process continuously produces a product of uniform composition and controllable physical properties.
- Its applicability is extended from critical excipients to micro encapsulation, aqueous coating, dry emulsions and dry elixirs.

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