Paper No. : 04
Paper Title: Unit Operations in Food Processing
Module- 17: Dryers used in Food Industries

17.1 Introduction

Drying or dehydrations is one of the ancient methods and important unit operations for preserving food. It is one of the most energy-intensive unit operations in postharvest processing. This unit operation is applied to reduce the water content of products such as various fruits, vegetables, cereals, pulses other agricultural and herbal products, etc. after harvest. The purpose of reducing the water content is to prolong the shelf-life of the products of bio-origin by reducing the water activity to a level low enough where growth of microorganisms, enzymatic reactions, and other deteriorative reactions are inhibited. Some bio-origin products such as herbs have to be dried before the active ingredients can be extracted. Furthermore, the products in the dry form weigh less and thus reduce transportation costs. The term dried and dehydrated are not synonymous; as per US department of agriculture dehydrated products the moisture content less than 2.5% (db) and dried food have moisture content more than 2.5 % (db).

The harvested bio-origin products are diverse in physical, chemical, and biochemical properties. A large assortment of dryers has been developed to dehydrate and preserve these products to meet different quality and cost requirements. Over 500 dryer types have been reported in the technical literature, and about 100 types are commercially available. Differences in dryer design are due to different physical attributes of the product, different modes of heat input, different operating temperature and pressure, different quality specifications on the dried product, etc. Most conventional dryers use hot air as the drying medium, convection as the single mode of heat transfer, and are operated at atmospheric pressure under steady drying conditions. This module will help the students understand the different drying principles, on which the the industrials dryers are based.

17.2.1 Tray dryer: In tray dryers, the food is spread out, generally quite thinly, on trays in which the drying takes place. Heating may be by an air current sweeping across the trays, by conduction from heated trays or heated shelves on which the trays lie, or by radiation from heated surfaces. Most tray dryers are heated by air, which also removes the moist vapours.

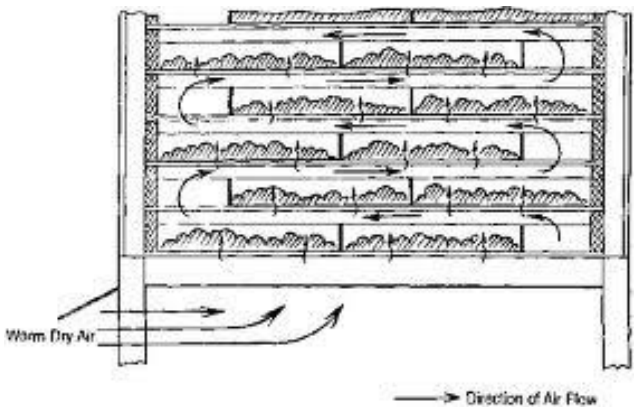


Fig17.1 Schematic diagram of a Tray Dryer (Source: www.howtopedia.org)

17.2.2 Tunnel Dryers

These may be regarded as developments of the tray dryer, in which the trays on trolleys move through a tunnel where the heat is applied and the vapours removed. In most cases, air is used in tunnel drying and the material can move through the dryer either parallel or counter current to the air flow. Sometimes the dryers are compartmented, and cross-flow may also be used. The air flow system could be (i) concurrent, in which the air moves in the same direction of the trolleys The air inside the tunnel may be concurrent, where the moving trucks, (ii), countercurrent, in which the air moves in the opposite direction to the trolleys, (iii) combination of concurrent and countercurrent flow, which is achieved by means of separate tunnels, parallel tunnels, or a centre –exhaust tunnel, and (iv) transverse flow, which is achieved by combining with inter-stage reheating of air and appropriate ducting to provide what is essentially a countercurrent low system.

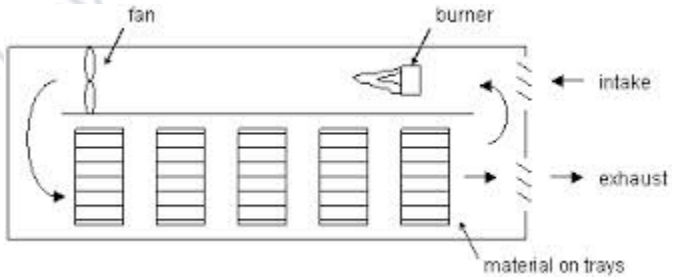


Fig 17.2 A Concurrent Tunnel dryer (Source: Conserval Engineering Inc.)

17.2.3 Roller or Drum Dryers

In these the food is spread over the surface of a heated drum. The drum rotates, with the food being applied to the drum at one part of the cycle. The food remains on the drum surface for the greater part of the rotation, during which time the drying takes place, and is then scraped off. Drum drying may be regarded as conduction drying. The variety of feed arrangement available ensures that solutions,

suspensions, and pastes of wide range of viscosities can be dried. This type of dryer is suited to many heat sensitive products since exposure to high temperature is limited to a few seconds.

The dryer consists of hollow metal cylinders that rotate on horizontal axes while heated internally by steam, hot water, or other heating medium and a scraper or Doctor's knife. Drum dryers can be classified in to single drum or twin drum. An important aspect considered when using drum dryer is the uniform thickness of the film applied to the drum surface, also the speed of rotation and heating temperature.

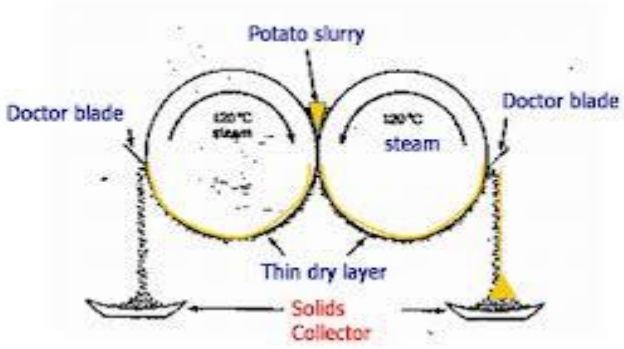


Fig17.3 Production of Potato Powder by Twin Drum dryer

17.2.4 Fluidized Bed Dryers

In a fluidized bed dryer, the food material is maintained suspended against gravity in an upward-flowing air stream. There may also be a horizontal air flow helping to convey the food through the dryer. Heat is transferred from the air to the food material, mostly by convection. A fluidized bed dryer consists of three important elements (1) distributor, (2) plenum chamber, (3) freeboard region and gas cleaning system. The distribution plate distributes the fluidization gas around the bed sufficiently evenly to avoid excessive local gas velocities. The plenum chamber provides a homogenous region of gas flow below the distribution plate. A conical shaped plenum chamber is preferred over spherical one. The free board region above the fluidized bed should be sufficiently high to allow disentrainment of particles which have been thrown up from the bed by transient local high flows of gas.

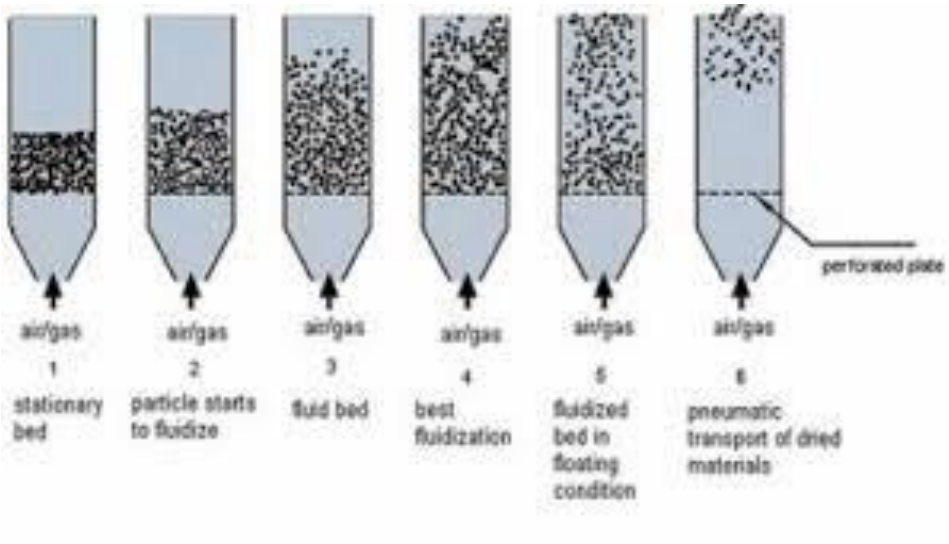


Fig17.4 Different stages of fluidization (www.pharmainfo.net)

17.2.5 Spray Dryers

By definition spray drying involves the atomization of a liquid feedstock containing solids in solution, suspension or emulsion, and directing the resulting spray of droplets into a flow of hot drying air. Contact takes place in a drying chamber. The atomization stages create a very large wet surface area in the form of millions of droplets which, when exposed to the hot drying air, results in the occurrences of very high rates of heat and mass transfer. Drying time becomes short and it is possible for product heating to be restricted to levels at which thermal degradation does not occur. The dryer body is large so that the particles can settle, as they dry, without touching the walls on which they might otherwise stick. Commercial dryers can be very large of the order of 10 m diameter and 20 m high. Spray drying involves both particle formation and drying which makes it special type of frying process. Similar to fluidized bed drying, flash drying; spray drying is a suspended particle processing operation. The main difference between spray drying, fluidized bed drying and flash drying are feed characteristics. The time taken for spray drying usually less than a minute, whereas in case of fluidized bed drying its is more than 1 hr and the materials into the feed system is fluid in case of spray drying whereas it is granular material in case of fluidized bed dryers. Spray dryer could be (i) concurrent, (ii) countercurrent or (iii) mixed flow types.

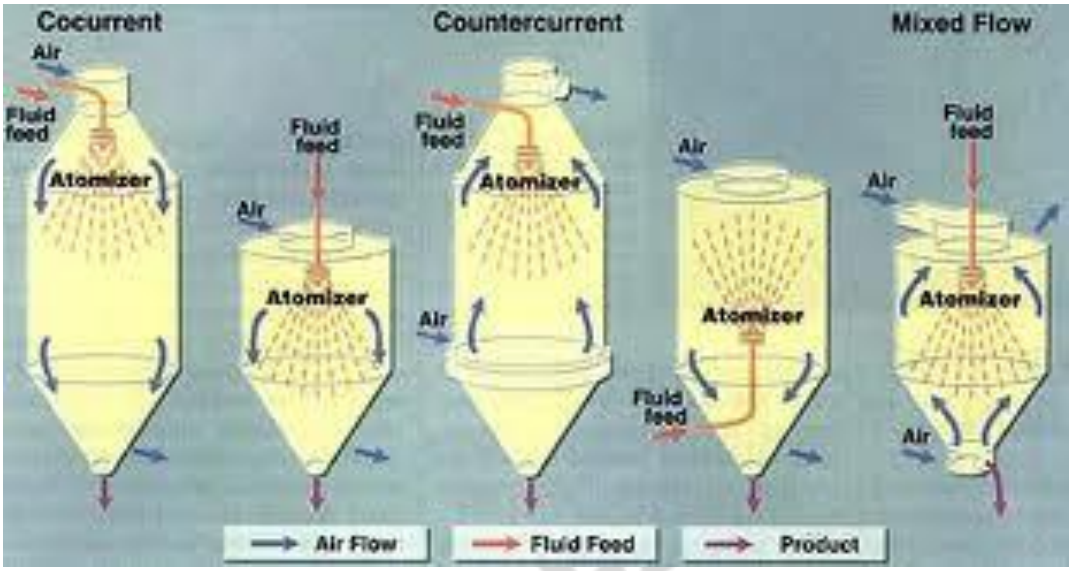


Fig17.5 Spray dryers with co-current and counter current flow (www.niroinc.com)

17.2.6 Pneumatic Dryers

In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particles in suspension. Heated air accomplishes the drying and often some form of classifying device is included in the equipment. In the classifier, the dried material is separated, the dry material passes out as product and the moist remainder is recirculated for further drying. Since the drying process is very rapid it is often termed as flash dryer. The basic type of pneumatic dryer consists normally of a straight vertical tube of circular square cross-section. Air and wet solids are introduced at the bottom of this tube. The dried solids, which are collected in a suitable particle separation device/ classifer, and the exhaust air, both leave at the top.

17.2.7 Rotary Dryers

Rotary dryers are widely used to dry relatively large throughputs of granular products and by-products. These dryers are characterized by a slowly rotating cylindrical drum, which is normally inclined at a small angle (0-5°), to the horizontal. The foodstuff is contained in a horizontal inclined cylinder through which it travels, being heated either by air flow through the cylinder, or by conduction of heat from the cylinder walls. In some cases, the cylinder rotates and in others the cylinder is stationary and a paddle or screw rotates within the cylinder conveying the material through. Wet feed is introduced into the upper end and dried product is withdrawn at the lower end.

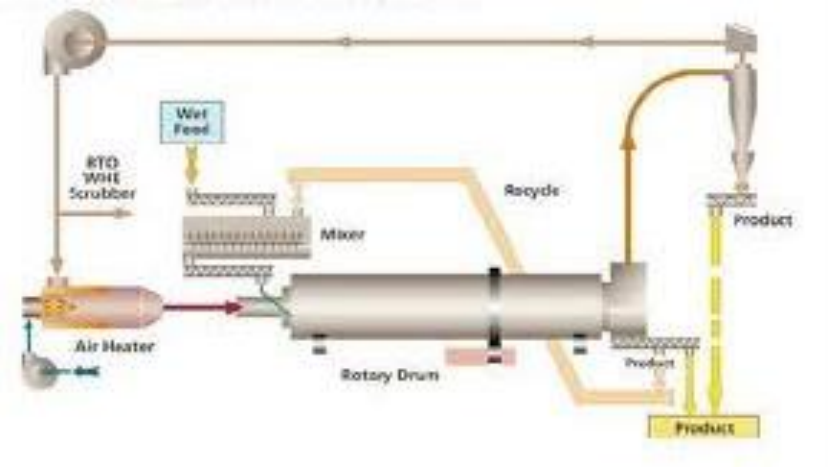


Fig17.6 Working principle of Rotary dryer (source: Gongyi Hengchang Inc.)

17.2.8 Trough Dryers

The materials to be dried are contained in a trough-shaped conveyor belt, made from mesh, and air is blown through the bed of material. The movement of the conveyor continually turns over the material, exposing fresh surfaces to the hot air.

17.2.9 Bin Dryers

In bin dryers, the foodstuff (usually grain) is contained in a bin with a perforated bottom through which warm air or unheated air is blown vertically upwards, passing through the material and so drying it. In these systems, grain is dried while stored in abin, which can either be flat bottomed or hopper-bottomed. Unheated or warm air is introduced into the stationary grain through a perforated floor. The moist air exits from the top or from a side. In some cases the grain after being dried with warm air is transported to a cooling and storage bin. But in most cases the bin dryers serve both as drying and storage unit.

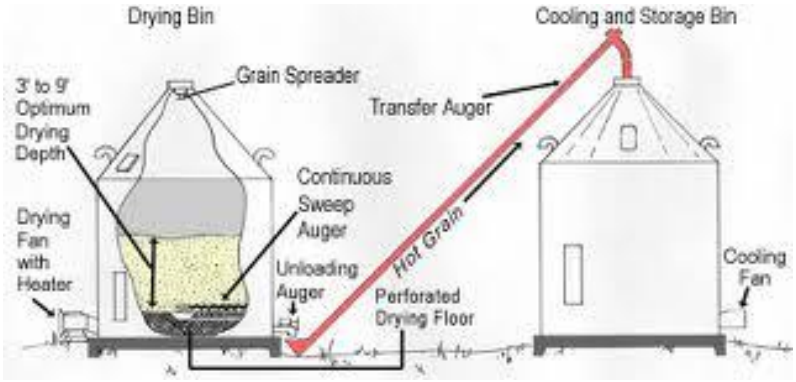


Fig17.7 Grain bin dryer (www.ruralenergy.wisc.edu)

17.2.10Belt Dryers

The food is spread as a thin layer on a horizontal mesh or solid belt and air / radiation passes through or over the material. In most cases the belt is moving, though in some designs the belt is stationary and the material is transported by scrapers. The heating source of the belt drying chamber could be hot air, electromagnetic radiation such as radio frequency and microwave, infrared etc.

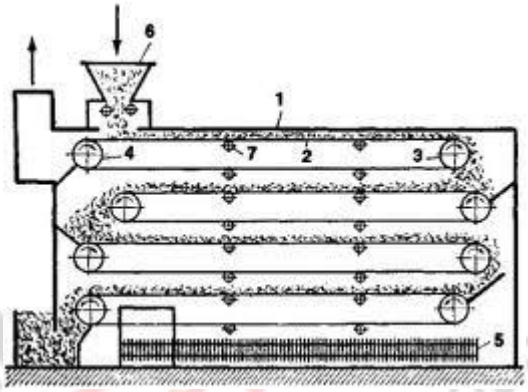
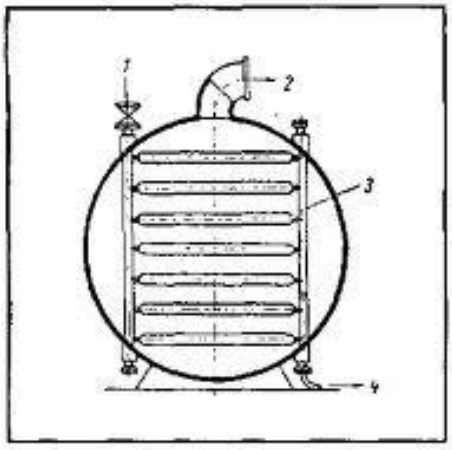


Fig17.8 Belt dryer (source: encyclopedia)

17.2.11Vacuum Dryers

Batch vacuum dryers are substantially the same as tray dryers, except that they operate under a vacuum, and heat transfer is largely by conduction or by radiation. The trays are enclosed in a large cabinet, which is evacuated. The water vapour produced is generally condensed, so that the vacuum pumps have only to deal with non-condensible gases. Another type consists of an evacuated chamber containing a roller dryer. In vacuum dryers, the removal of moisture from the food product takes place under vacuum, where the boiling point of water decreases, so application of lower heat through conduction or radiation can remove the moisture from the product, so that the heat sensitive components of the food are not degraded as they would at higher temperatures.



1. Steam inlet
2. Vacuum
3. Heating plate
4. Condensed steam

Fig17.9 Vacuum dryer (www.fao.org)

17.2.12Freeze Dryers

Freeze drying is known to be the best method for drying as far as quality is concerned compared to other methods of drying. During this process, the product is frozen and the frozen free water heated to low temperature, is directly converted to gas on application of vacuum in a process, known as sublimation and condensation of gas. Since this process is carried out at low temperature, microbial activity, enzymatic activity and other biochemical processes responsible for unsolicited changes in the food during the dehydration processes are substantially retarded, leading to retention of color, flavor and nutrition of the food product to a large extent. But the flack side of this process is higher running and operating cost pertaining to freezing of the food product, slightly heating the frozen product to allow sublimation of ice under vacuum, condensation of ice and mechanical energy requirement for maintenance of vacuum. Moreover, there is some loss of water soluble volatiles with the sublimation of ice, structural change making the final product tasting bland.

In a Freeze dryer, the moisture content in the food material is frozen prior to drying and is then sublimed, i.e., passed to the gas phase directly from the solid phase, below the melting point of the solvent. Freeze drying can only take place if the partial pressure of the vapor in the drying chamber is lower than the water vapor pressure above the product. Trays of products are placed on shelves that could be heated. After that pressure is applied, where the pressure should be less than vapour pressure of water. After this pressure is reached, heat is applied to the shelves to provide the energy required for sublimation of ice, which is known as primary drying. After this when the ice is gone, additional drying time is required to remove water. This phase is called secondary drying. Pressure can be reduced by a high vacuum pump; the vapor produced by sublimation is removed from the system by converting it into ice in a condenser, operating at very low temperatures, outside the freeze drying chamber.

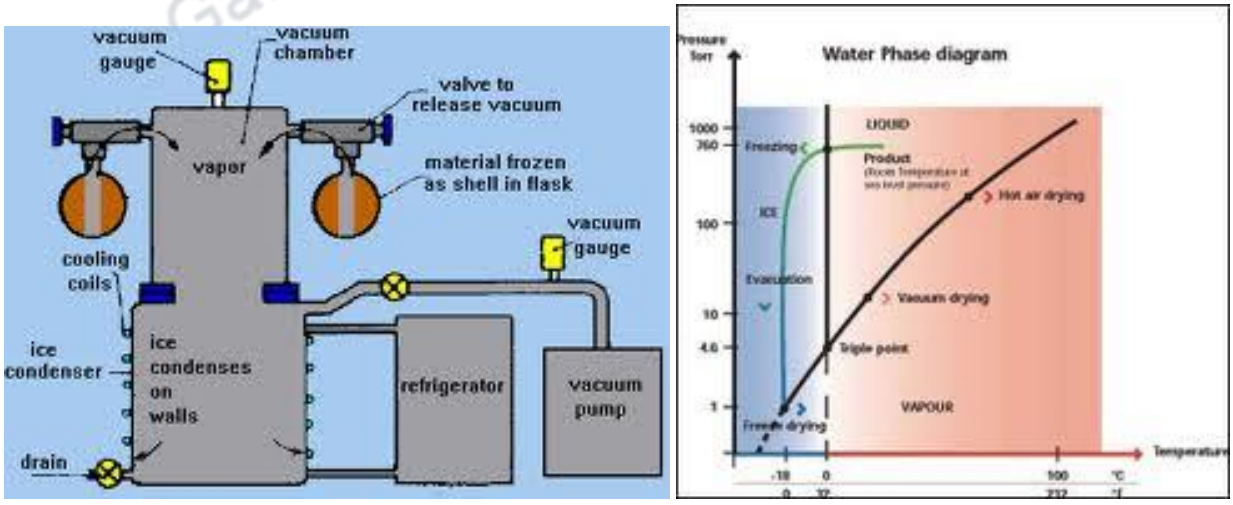


Fig17.10 Freeze dryer with components and phase diagram (www.rpi.edu)

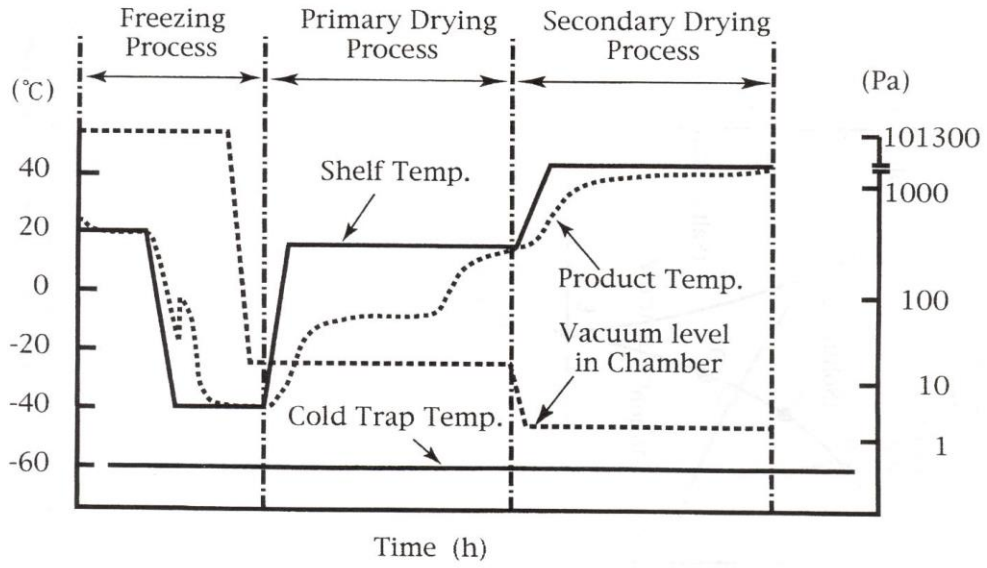


Fig.17.11 Plot of process variable in freeze drying process

17.3 Summary

Drying is important to food industry as it consumes up to 10% of the total energy used in that sector. The selection of dryer is, however, driven more by product quality consideration than by energy saving potential. Environmental impact and safety operation are the additional factors which influence the selection of dryers. While over 200 different dryers have found various applications in industry, only about 20 basic types and their physical forms are commonly used in practice. The wide range of dryers is due to the diverse physical forms of the products to be dried, the production rates desired, and the quality constraint on the dried product. The wet feedstock may be in the form of liquid (slurry, suspension or solution), a solid (particulate, sheet-like, pelletized, extruded forms) or pasty.

References:

1. *Industrial Drying of Foods*, Christopher G. J. Baker, Blackie Academic & Professional,
2. *Unit operations in food processing*, http://www.nzifst.org.nz/unitoperations/drying7.htm