Preservation by Dehydration

Introduction

- The preservation of foods by drying is the time-honored and most common method used by humans and the food processing industry.
- Dehydration of food is one of the most important achievements in human history, making humans less dependent upon a daily food supply even under adverse environmental conditions.
- Though in earlier times drying was dependent on the sun, nowadays many types of sophisticated equipment and methods are used to dehydrate foods.

Introduction

- During the past few decades, considerable efforts have been made to understand some of the chemical and biochemical changes that occur during dehydration, and develop methods for preventing undesirable quality losses.

State of Water in Foods

- The terms dried and dehydrated are not synonymous.
- Dehydrated foods are those with no more than 2.5% water (dry basis), while the term dried foods applies to any food product with more than 2.5% water (dry basis).
- The concept of bound water and free water has been developed from drying principles, and it is important for dried products – for its stability during processing and storage.
- Water exists in foods in different forms or states.

State of Water in Foods

- In foods, water having properties different from those of pure water can be defined as bound water
- The binding energy of different states of bound water affects the drying process, since it requires more energy to remove bound water than free water.

Different forms of bound water

Monolayer
Unfreezable water
Immobile water
Non solvent water

Heating Methods in Drying

- Heating air using either an electric heater or flue gas is the conventional heating method used for drying foods.
- In this case, heat transfer from the gas to the product occurs mainly through convection.
- The heating method is another important aspect of drying, in terms of quality as well as energy cost.
- Microwave, infrared, radio frequency, refractance window, and dielectric heating use electromagnetic wavelength spectrum as a form of energy, which interacts with the materials, thus generating heat and increasing the drying rate dramatically.

Heating Methods in Drying

- Dielectric drying uses frequencies in the range of 1–100 MHz, whereas microwave drying uses frequencies in the range of 300–300,000 MHz.
- Microwave heating is rapid, more uniform in the case of liquids, and more energy efficient than the hot-air method.
- Applying microwave energy under vacuum affords the advantages of both vacuum drying and microwave drying, thereby providing improved energy efficiency and product quality.
- The energy can be applied in pulsed or continuous mode; however, pulsed microwave drying is more efficient than continuous drying.

Heating Methods in Drying

- The use of electro-technology in drying is gaining priority in the food industry to improve drying efficiency as well as quality.

Dielectric • induces molecular friction in water molecules to produce heat • is determined in part by the moisture content of food • to preserve foods
Ohmic • heating is due to the electrical resistance of a food • heating depends on the electrical resistance of food • to preserve foods
IR • energy is simply absorbed & converted to heat • the extent of heating by radiant energy depends on surface characteristics & colour of food • used to alter the eating qualities by changing the surface colour, flavour & aroma

Drying Methods

- Drying processes can be broadly classified, based on the water-removing method applied, as
    - Thermal drying,
    - Osmotic dehydration, and
    - Mechanical dewatering.

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  - Thermal drying,
  - Osmotic dehydration, and
  - Mechanical dewatering.
- Thus, thermal drying can be divided further into three types:
  - Air drying,
  - Low air environment drying, and
  - Modified atmosphere drying.

Drying Methods

- Consideration should be given to many factors before selecting a drying process. These factors are
- The type of product to be dried,
- Desired properties of the finished product,
- Allowable temperature tolerance,
- The product's susceptibility to heat,
- Pretreatments required,
- Capital and processing costs, and
- Environmental factors.

Drying Methods

- Capital and processing costs, and
- Environmental factors.
- There is no one best technique of drying that is applicable for all products.

Thermal Drying

- Thermal drying is one of the most widely used methods of drying foods.
- In this process, heat is mainly used to remove water from the foods.
- The mechanisms of moisture transfer depend mainly on the types or physicochemical state of food materials and the drying process.
- Food materials can be classified as
- Homogeneous gels,
- Porous materials with interconnecting pores or capillaries, and
- Materials having an outer skin that is the main barrier to moisture flow.
- The type or structure of foods always plays an important role in the drying process.

Thermal Drying

- Typical drying rate curves are shown in Figures 1 and 2.
- The moisture content at which the change from the first to the second period occurs is known as the critical moisture content.
- Typically, two falling rate periods are observed for both hygroscopic and nonhygroscopic solids.
- The first falling rate period is postulated to depend on both internal and external mass transfer rates; while the second period, during which drying is much slower, is postulated to depend entirely on internal mass transfer resistance.

Thermal Drying

- The slower rate may be due to the solid–water interaction or glass–rubber transition.
- The drying behaviors of food materials depend on the porosity, homogeneity, and hygroscopic properties.
- The immediate entrance into the falling rate is characteristic of hygroscopic food materials.

Methods of drying & dehydration

Air-Drying Methods

- In the case of air drying, atmosphere is used as the drying medium and heat as different modes could be applied in the process.

Sun Drying

- Earlier, only sun drying was used for drying.
- In this process, foods are directly exposed to the sun by placing them on the land or left hanging in the air.

Methods of drying & dehydration

- The main disadvantages of this type of drying are
- Contaminations from the environment,
- Product losses and contaminations by insects and birds,
- Floor space requirements,
- Difficulty in controlling the process, and
- Bad odor.
- When the climate is not particularly suitable for air drying or better quality is desired, mechanical air drying is mainly used.

Solar Drying

- Solar drying is an extension of sun drying that uses radiation energy from the sun.
- Solar drying is a nonpolluting process and uses renewable energy.
- Moreover, solar energy is an abundant energy source that cannot be monopolized.
- However, solar drying has several drawbacks that limit its use in large-scale production.
- These are the need for large areas of space and for high labor inputs, difficulty in controlling the rate of drying, and insect infestation and microbial contamination.

In-Store Drying

- In-store drying can also be called low-temperature in-bin drying.
- It may be used when grains are stored until milled or sold.
- Weather conditions in tropical climates are less favorable for in-store drying, due to high ambient temperatures and relative humidity values.
- Two-stage drying can produce good quality by preventing discoloration of high-moisture grains and reduced cracking of skin dry kernels.

In-store drying (also referred to as low-temperature drying or near ambient air drying) **uses a different drying principle than heated air dryers**. It utilizes the drying potential of the ambient air which is blown through the grain bulk in the storage bin.

Convection Air Drying

- Cabinet- and bed-type dryers (i.e., kiln, tray, truck tray, rotary flow conveyor, and tunnel) fall into the first generation.
- This is the simplest drying technique, which takes place in an enclosed and heated chamber.
- The drying medium, hot air, is allowed to pass over the product, which has been placed in open trays.
- Convection drying is often a continuous process and is mostly used for products that are relatively low in value.

Convection Air Drying

- Air drying is usually accomplished by passing air at regulated temperature and humidity over or through the food in a dryer.

Convection Air Drying

- Factors that affect the rate of drying are temperature, humidity, air velocity and distribution pattern, air exchange, product geometry and characteristics, and thickness.
- The sample is usually placed on mesh trays in one layer or in bulk on a bed or hung from a string for better air circulation over the product.

Convection Air Drying

- The relative humidity (a measure of dryness) is lower when air temperature is raised.
- A dryer must expel air to get rid of moisture, thereby allowing new, lower humidity air to enter the system. However, this process causes heat loss from the dryer.
- In many cases, two or multistage drying with different conditions could be used, for example, initial drying at 90°C and then the second or final stage at 60°C.

Explosive Puff Drying

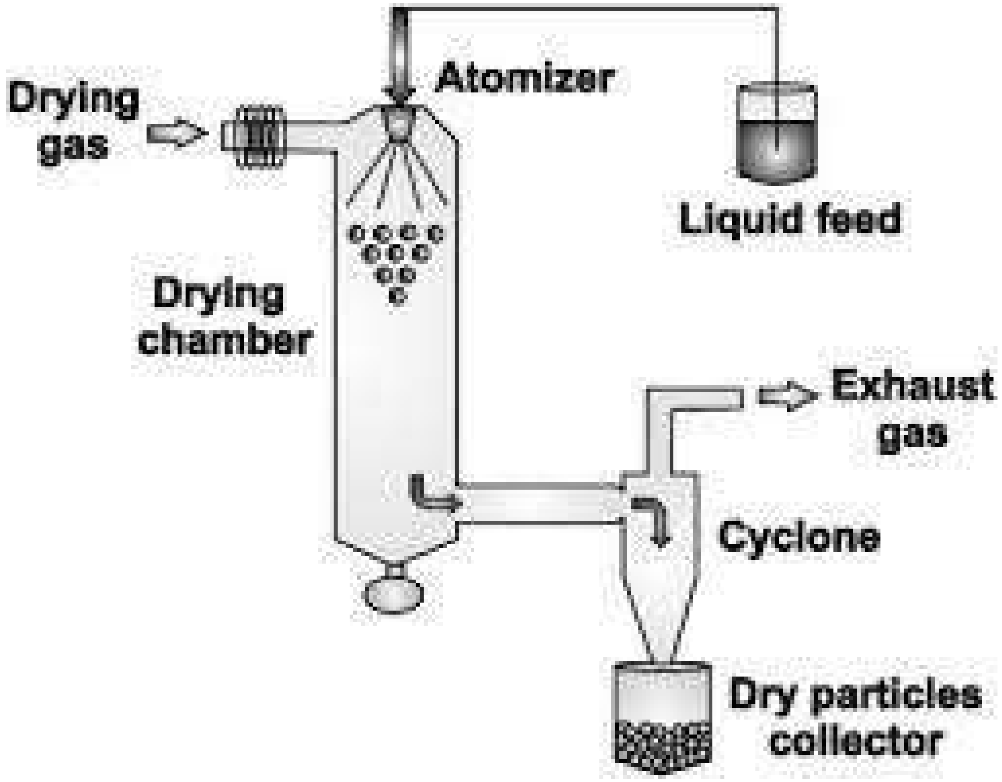
- Explosive puff drying uses a combination of high temperature and high pressure, and a sudden release of the pressure (explosion) to flush superheated water out of a product.
- This method gives a product of good rehydrability.
- However, the high heat can degrade food quality, and the explosion puffing may compromise product integrity.

Spray Drying

- Spray drying is used to remove water from a free-flowing liquid mixture, thus transforming it into a powder form.
- The fluid to be dried is first atomized by pumping it through either a nozzle or a rotary atomizer, thus forming small droplets with large surface areas.
- The droplets immediately come into contact with a hot drying gas, usually air.
- The liquid is very rapidly evaporated, thus minimizing contact time and heat damage.

Spray Drying

- Disadvantages include the size of the equipment required to achieve drying is very large and very oily materials might require special preparation to remove excessive levels of fat before atomization.
- Ultrasonication in the chamber can be used instead of complex atomization to produce small-diameter droplets in spray drying.


Atomizer
Drying gas
Liquid feed
Drying chamber
Exhaust gas
Cyclone
Dry particles collector

Fluidized Bed Drying

- This technique involves the movement of particulate matter in an upward-flowing gas stream, usually hot air.
- Fluidization mobilizes the solid particulates, thus creating turbulences on the solid surfaces, which increases the drying rate.
- The hot gas is introduced at the bottom of a preloaded cylindrical bed and exits at the top.
- In some cases, a vibratory mechanism is used to increase the contact of the product with the hot gas.

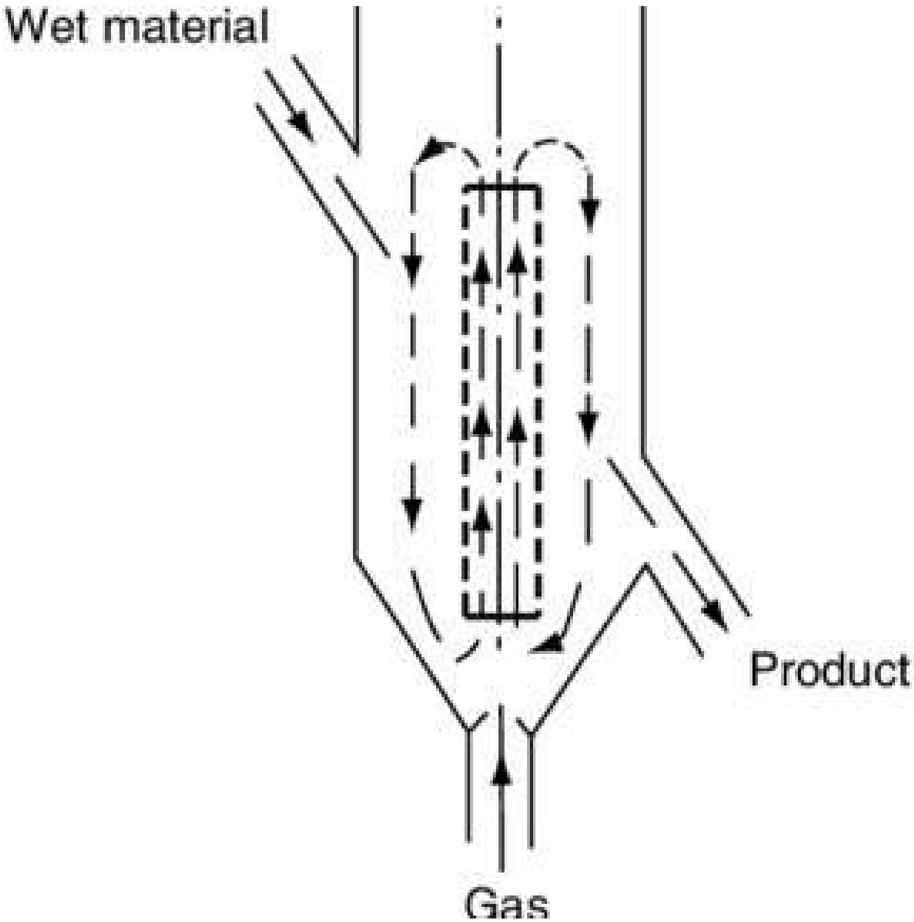
Fluidized Bed Drying

- Fluidized bed drying is usually carried out as a batch process and requires relatively small, uniform, and discrete particles that can be readily fluidized.
- The main advantages of fluidized bed drying are uniform temperature and high drying rates, thus less thermal damage.
- A rotating chamber is also used with the fluidized bed, thus increasing centrifugal force to further increase the drying rate and mixing.
- The use of a solid carrier, such as sea sand, and wheat bran could prevent the biomaterial from deterioration due to thermal shock.

Fluidized bed dryer

Spouted Bed Drying

- In a spouted bed dryer, a jet of heated gas enters the chamber at the center of a conical base.
- The food particles are rapidly dispersed in the gas, and drying occurs in an operation similar to flash drying.
- **Ball Drying**
- In this method, the material to be dried is added at the top of the drying chamber through a screw conveyor.
- The material within the drying chamber comes into direct contact with heated balls made from ceramic or other heat-conductive material.



Spouted bed drying

Ball Drying

- In this method, the material to be dried is added at the top of the drying chamber through a screw conveyor.
- The material within the drying chamber comes into direct contact with heated balls made from ceramic or other heat-conductive material.
- Drying occurs primarily by conduction. Hot air is passed through the bottom side of the chamber.
- When the product arrives at the bottom of the chamber, it is separated from the balls and collected.

Rotary Drum Drying

- Rotary drum dryers are cylindrical shells 1–5 m in diameter, 10–40 m in length, and rotating at 1–8 rpm with a circumferential speed of approximately 0.2–0.4 m/s.
- These conditions depend on the product types to be dried.
- The dryers are designed to operate at a nearly horizontal position, inclined only by 2°–6° to maintain the axial advance of solids, which are fed from the upper end of the dryer body.

Rotary Drum Drying

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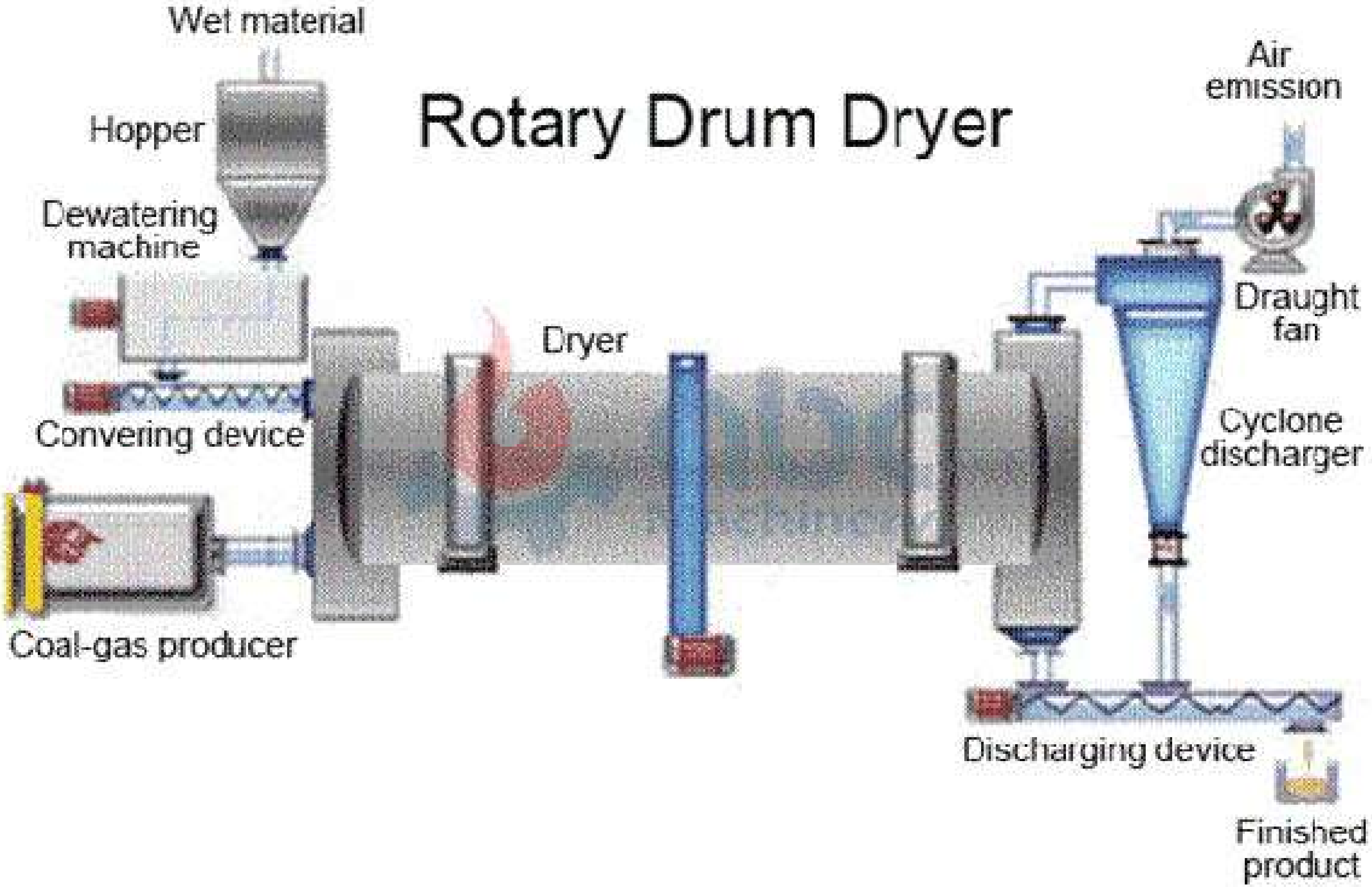
- **Drum Drying**
- This technique removes water from a slurry, paste, or fluid that has been placed on the surface of a heated drum.
- The dryer may comprise either a single or a double drum.
- Drum drying is typically a continuous operation, and care must be taken to ensure that the product that is to be dried adheres well to the drying surface.



Rotary Drum Dryer
Wet material
Hopper
Dewatering machine
Convering device
Coal-gas producer
Dryer
Air emission
Draught fan
Cyclone discharger
Discharging device
Finished product

Low Air Environment Drying

Vacuum Drying

- Vacuum drying of food involves subjecting the food to a low pressure and a heating source.
- The vacuum allows the water to vaporize at a lower temperature than at atmospheric conditions, thus foods can be dried without exposure to high temperature.
- In addition, the low level of oxygen in the atmosphere diminishes oxidation reactions during drying.
- In general, color, texture, and flavor of vacuum-dried products are improved compared with air-dried products.

Vacuum dryer

Freeze Drying

- In freeze drying, frozen material is subjected to a pressure below the triple point (at 0°C, pressure: 610 Pa) and heated to cause ice sublimation to vapor.
- A schematic diagram of the different states of water with triple point is shown in Figure.3.
- This method is usually used for high-quality dried products, which contain heat-sensitive components such as vitamins, antibiotics, and microbial culture.
- The virtual absence of air and low temperature prevents deterioration due to oxidation or chemical modification of the product.

Freeze dryer

Heat Pump Drying

- The heat pump dryer is a further extension of the conventional convection air dryer with an inbuilt refrigeration system.

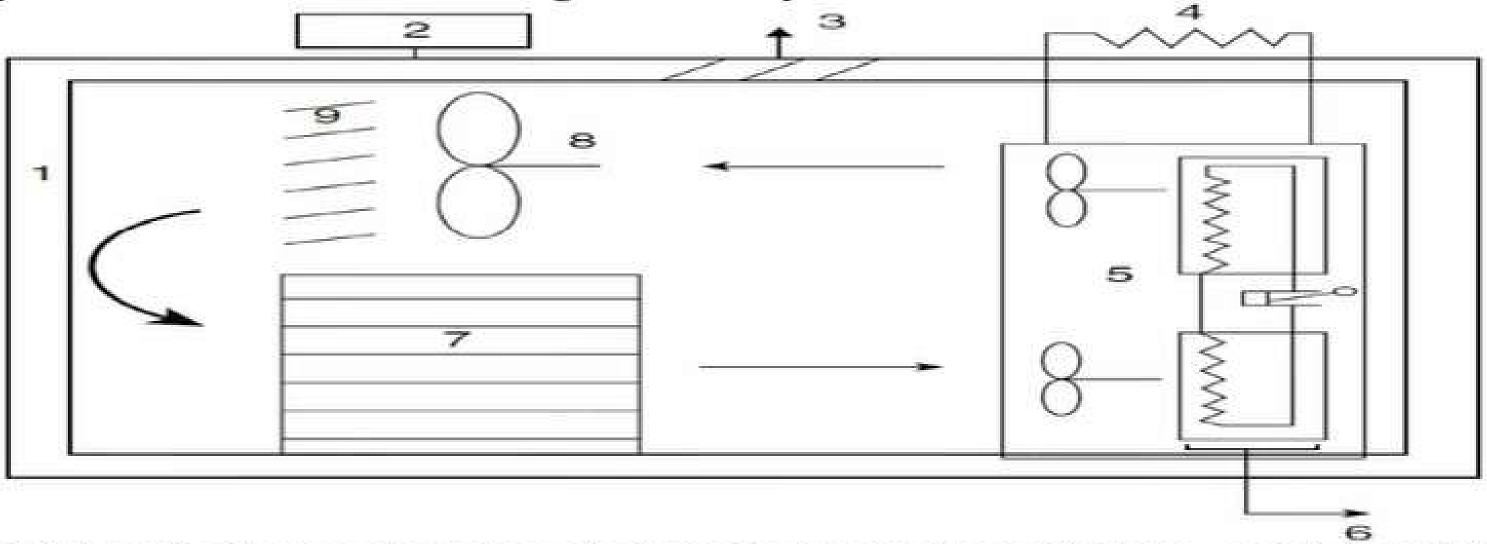


Figure 4: Schematic diagram of operation of a typical heat pump dryer. (1) Vapor – scaled & insulated structure; (2) Humidifier; (3) Over heat vent; (4) External condenser; (5) Heat pump dehumidifier; (6) Condensate; (7) Product tray; (8) Primary sir circulation fan & (9) Air distributor.

Heat Pump Drying

- The heat pump dryer is a further extension of the conventional convection air dryer with an inbuilt refrigeration system as shown in the Figure. 4.
- Dry heated air is supplied continuously to the product to pick up moisture.
- This humid air passes through the evaporator of the heat pump where it condenses, giving up its latent heat of vaporization to the refrigerant in the evaporator.
- This heat is used to reheat the cool dry air passing over the hot condenser of the heat pump.

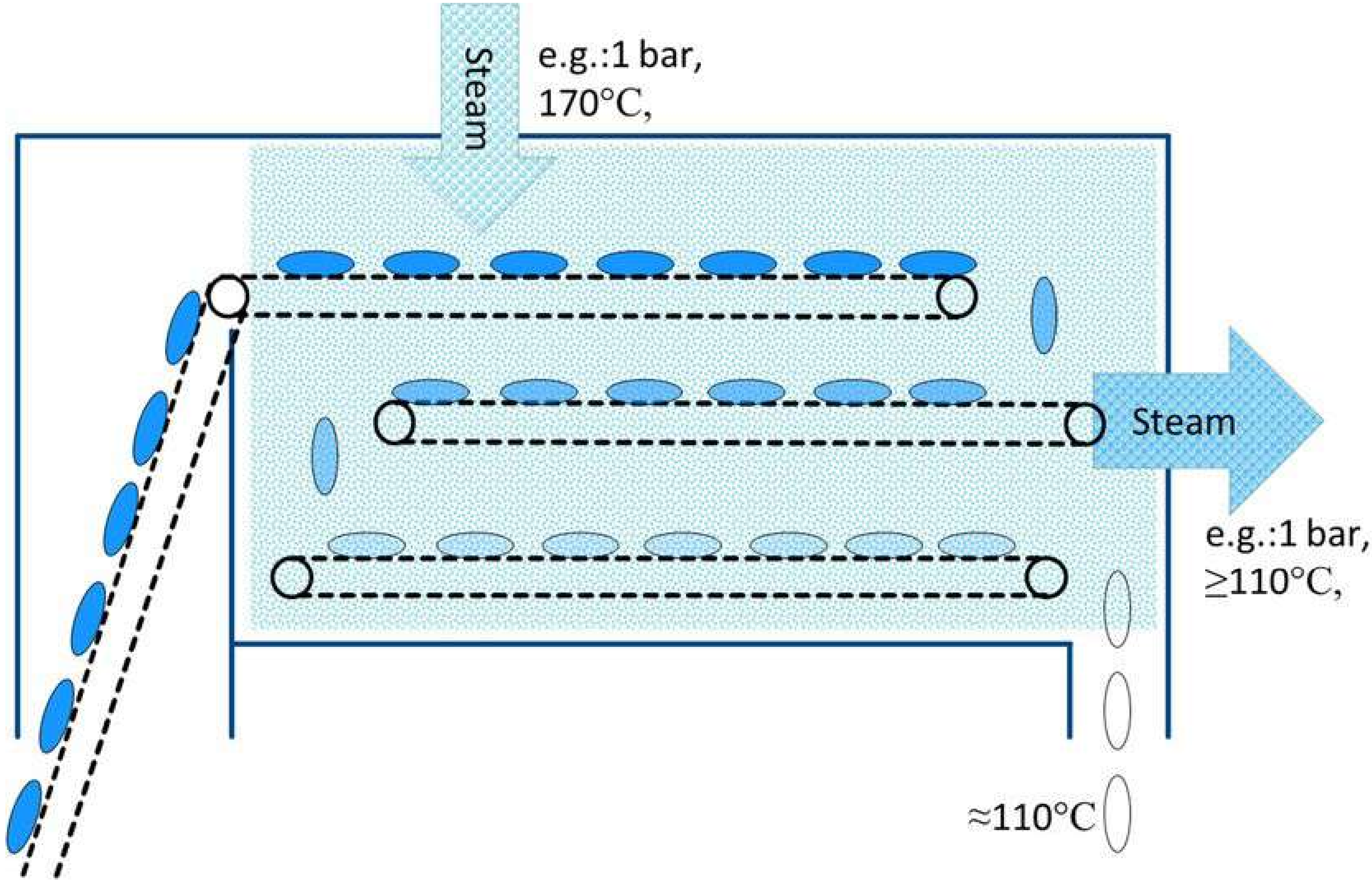
Heat Pump Drying

- Thus, the latent heat recovered in the process is released at the condenser of the refrigeration circuit and used to reheat the air within the dryer.
- The use of the heat pump dryer offers several advantages over conventional hot air dryers for drying food products, including higher energy efficiency, better product quality, the ability to operate independent of outside ambient weather conditions, and zero environmental impact.
- In addition, the condensate can be recovered and disposed of in an appropriate manner, and there is also the potential to recover valuable volatile components from the condensate.

Heat Pump dryer

Superheated Steam Drying

- Superheated steam is used as a drying medium.
- The main advantages of this type of drying are that it can provide an oxygen-free medium for drying, and process steam available in the industry can be used without any capital cost.
- An oxygen-free medium has the potential to provide high-quality food products; however, it is important to generate more information regarding quality improvement and processing efficiency.



Superheated steam drying

Impingement Drying

- Impingement drying is an old technology that has only recently been applied to food products.
- An impingement dryer consists of a single gas jet (air or superheated steam) or an array of such jets, impinging normally on a surface.
- There are a great variety of nozzles that can be used, and selection of the nozzle geometry and multinozzle configuration have important relevance on the initial and operating costs, and product quality.
- Some characteristics of impingement drying include rapid drying, popular for convection drying, and the large variety of nozzles available (multizones).

Impingement dryer

Smoking

- Smoking foods is one of the most ancient food preservation processes, and in some communities one of the most important.
- The use of wood smoke to preserve foods is nearly as old as open-air drying.
- Although not primarily used to reduce the moisture content of food, the heat associated with the generation of smoke also causes a drying effect.

Smoking

- Smoking foods is one of the most ancient food preservation processes, and in some communities one of the most important.
- The use of wood smoke to preserve foods is nearly as old as open-air drying.
- Although not primarily used to reduce the moisture content of food, the heat associated with the generation of smoke also causes a drying effect.
- The main purposes of smoking are it imparts desirable flavors and colors to the foods, and some of the compounds formed during smoking have a preservative effect (bactericidal and antioxidant) due to the presence of a number of compounds.

Smoking

- In many cases, smoking is considered as a pretreatment rather than a drying process.

Smoking

Pretreatments

- Pretreatments are common in most of the drying processes in order to improve product quality, storage stability, and process efficiency.
- In recent years, an improvement in quality retention of the dried products by altering processing strategy and pretreatment has gained much attention.

Blanching

- Blanching is a process of preheating the product by immersion in water or steam.
- The main purpose of blanching is to inactivate the naturally occurring enzymes present in foods, since enzymes are responsible for off-flavor development, discoloration or browning, deterioration of nutritional quality, and textural changes in food materials.
- Other advantages are that it removes air-bubbles from vegetable surfaces and from intercellular spaces, reduces the initial microbial load, cleans raw food materials initially, facilitating preliminary operations such as peeling and dicing, and improving color, texture and flavor under optimum conditions.

Sulfur Dioxide Treatment

- Sulfur dioxide preserves the texture, flavor, vitamin content, and color that make food attractive to the consumer.
- Sulfur dioxide treatment is used widely in the food industry to reduce the fruit-darkening rate during drying and storage, and preserves ascorbic acid and carotene.
- Sulfur dioxide taken up by the foods displaces air from the tissue in plant materials, softens cell walls so that drying occurs more easily, destroys enzymes that cause darkening of cut surfaces, shows fungicidal and insecticidal properties, and enhances the bright attractive color of dried fruits.
- Permitted levels of sulfur dioxide and other additives (solutes) in dried foods vary from country to country.

Salting or Curing

- Salting or curing is a natural type of osmotic dehydration.
- Curing was originally developed to preserve certain foods by the addition of sodium chloride.
- In the food industry, the application of curing is related only to certain meat, fish, and cheese products.
- Today sodium chloride, and sodium and potassium nitrite (or nitrate) are considered as curing salts.
- Salting is one of the most common pretreatments used for fish products.
- It converts fresh fish into shelf-stable products by reducing the moisture content and acting as a preservative.

Freezing Pretreatment

- Freezing treatment affects the drying process.
- The rehydration rate of air- and vacuum-dried fruits and vegetables subjected to freezing treatment increased to a level comparable with that of freeze-dried products.
- It is also noticed that the longer the duration of freezing, the better the rehydration kinetics of dried products.
- This is due to the formation of large ice crystals by slow freezing.

Cooking

- Cooking at different pressure levels before drying can destroy microorganisms and affect the physicochemical properties of dried products.
- The bacterial load on the final product can thus be reduced considerably, and the cooked product can be minced and spread evenly on drying trays with much less trouble than the raw material.
- Precooking is usually used for rice, beef, fish, and beans.
- Formation of superficial pellicle (case-hardening) may be avoided by precooking, which considerably retards drying.

Chemicals Used for Dipping Treatment

Other Dipping Pretreatments

- Dipping treatment with chemicals is also used in addition to blanching or sulfite treatment.
- The dipping treatment is a process of immersion of foods in a solution containing additives.

Chemicals Used for Dipping Treatment

Type	Compounds
Chemicals	
▪ Esters	Methyl oleate, ethyl oleate, butyl oleate
▪ Salts	Potassium carbonate, sodium carbonate, sodium chloride, potassium sorbate, sodium polymetaphosphate
▪ Organic acids	Oleic acid, steric acid, caprillic acid, tartaric acid, oleanolic acid
▪ Oils	Olive oil
▪ Alkali	Sodium hydroxide

Chemicals Used for Dipping Treatment

Type	Compounds
Chemicals	
▪ Wetting agents	Pectin, tween, nacconol
▪ Others	Sugar, liquid pectin

DRYING CAUSES

- Denaturation of proteins
- a general loss of structure
- browning reactions
- discolouration

Browning is due to Maillard reaction or enzyme catalyzed reaction. It can be avoided by storing at low temperature and enzyme inactivation by blanching or steaming before drying

CHANGES DURING DRYING:

- Food materials do not have perfect elasticity and water is no removed evenly throughout food as it is dried and causes **shrinkage**.

- Due to high surface temperature and unbalanced drying, dry skin will form and causes **case hardening**.

- **Enzymatic browning** of products due to poor blanching.

- **Caramelization** of sugars due to excess heat.

- Loss of volatile flavor constituents.

- Partial loss of some essential nutrients like Vit C.

Losses while drying/dehydration

Vitamins:
Vitamin A: 50-70% loss
Vitamin B: 50-60% loss
Vitamin C: 80-90% loss

Carbohydrates: None
Proteins: Denatured
Fats: None
Minerals: None

Vegetable	Ratio (Fresh:dried)
Bean and Potato	7:1
Onion	10:1
Okra	12:1
Bitter gourd	16:1
Cabbage and carrot	18:1
Pumpkin and spinach	22:1
Tomato	27:1
Turnip	28:1
Brinjal	33:1
Cauliflower	35:1

Fruit	Yield (%)
Apple	10-15
Apricot	15-19
Banana	14-20
Grape	20-27
Peach	15-19
Pear	15-19

Water content after drying:

Vegetables: 10-20%
Fruits: 6-8%

Vegetables: Peas, white onion
Fruits: Fig, Grapes, Banana

Drier types	Food types
a) Air convection driers	
1) Kiln	Pieces
2) Cabinet, tray or pan	Pieces, purees, liquid
3) Tunnel	Pieces
4) Continuous conveyor belt	Pieces, purees, liquids
5) Belt through	Pieces
b) Drier type	
1) Air lift	mall pieces granules
1) Fluidized bed	Small pieces, granules
1) Spray	Liquid purees
c) Drum or roller driers	
1) Atmospheric	Purees, liquids
2) Vacuum	Purees, liquids
d) Vacuum driers	
1) Vacuum shelf	Pieces, purees, liquid
2) Vacuum belt	Purees, liquids
3) Freeze driers	Pieces, liquids

Vegetable	Blanching		Drying time (hrs)
	Method	Time (mins)	
Beets	cook before drying		3½–5
Carrots	steam	3–3½	3½–5
	water	3½	
Corn	not necessary		6–8
Garlic	not necessary		6–8
Horseradish	not necessary		4–10
Mushrooms	not necessary		8–10
Okra	not necessary		8–10
Onions	not necessary		3–6
Parsley	not necessary		1–2
Peas	steam	3	8–10
	water	2	
Peppers	not necessary		2½–5
Potatoes	steam	6–8	8–12
	water	5–6	
Pumpkin	steam	2½–3	10–16

Flow sheet for drying / dehydration of fruits and vegetables

Fruit and vegetable
(Mature and free from insects and disease)

↓

Washing

↓

Peeling

↓

Preparation

↓

Blanching

↓

Spreading on flat-wooden trays

↓

Sulphuring
(usually @ 1.8-3.6 kg/ton of fruits)

↓

Drying/ Dehydration
(with occasional stirring)

↓

Sweating

↓

Packing
(Air tight container or polythene bags)

↓

Storage
(At ambient temperature in dry place)

Intermediate-Moisture Foods (IMF)

Intermediate-moisture food or semimoist foods, contain moderate levels of moisture, of the order of 20-50% by weight, which is less than is normally present in natural fruits and vegetables, but more than is left in conventionally dehydrated products. In addition, Intermediate-moisture food contains sufficient dissolved solute to decrease water activity below that required to support microbial growth.

BENEFIT OF DRIED FRUIT

- Dried fruits are good sources of phytochemicals.
- Dried fruits are an important source of antioxidants in the diet.
- Dried fruits, such as prunes, provide pectin, a soluble fiber that may lower blood cholesterol.
- Dried fruits, such as raisins, are a source of prebiotic compounds in the diet.
- Dried apricots and peaches are good sources of carotenoids.
- Dried fruits contain organic acids such as tartaric acid (raisins) and sugar alcohol such as sorbitol (prunes).

Conclusion

- Drying reduces the water activity, thus preserving foods by avoiding microbial growth and deteriorative chemical reactions.
- The effects of heat on microorganisms and the activity of enzymes are also important in the drying of foods.
- In the case of foods to be preserved by drying, it is important to maximize microorganism and enzyme inactivation for preventing spoilage and enhancing safety, and reduce the components responsible for the deterioration of the dried foods.
- Also, in the case of drying bacterial cultures, enzymes, or vitamins, minimum inactivation of the microorganism and enzyme is required.

Thank you

Acknowledgements:
https://www.youtube.com/watch?v=k-KHRJkVaGI