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A REVIEW ON COMPARISON OF DRYERS

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Abstract:

It is a mass transfer process resulting in the removal of moisture or another solvent, by evaporation from a solid, semisolid or liquid to end in a solid state. To achieve this, there must be a source of heat. Drying is most used in manufacturing as a unit process in the preparation of granules, which can be dispensed in bulk or converted into tablet or capsules. The present work is aimed to explain comparison of different dryers.

Keywords: Drying, Hot air oven, Tray dryer, Vacuum dryer, Drum dryer

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INTRODUCTION:

Drying involves removal of water or another solvent by evaporation from a solid, semi-solid or liquid by application of heat and finally a liquid free solid product is obtained. In general, drying is accomplished by thermal techniques but non-thermal drying processes such as squeezing wetted sponge, adsorption by desiccant and extraction are also used. Drying done to get a stable dry product and only removal of less amount of moisture and emphasize on solid product.

OBJECTIVES:

The main objectives of drying include preservation and increasing shelf life by reducing water content and water activity. Reduce space requirements for storage and transport. In pharmaceutical technology drying is carried out for one or more of the following reasons.

- To avoid or eliminate moisture which may lead to corrosion and decrease the product or drug stability.
- To improve or keep the good properties of a material like granules.eg. Flowability, compressibility.

APPLICATIONS OF DRYING

In pharmaceutical industries, drying is carried out for one or more of the following reasons:

- **Preparation of bulk drug**: In the preparation of bulk drug, drying is the final stage of processing. A few examples are- dried aluminium hydroxide, spray dried lactose and powdered extracts.
- **Preservation of drug products:** Drying is necessary to avoid deterioration. For example, Protection of blood products**,** skin, tissues and crude drug from microbial growth.
- **Improved characteristics:** Drying produces materials of spherical shape, uniform size, free flowing and enhanced solubility.
- **Improved handling:** To reduce the cost of transportation of large volume of materials. To make materials easy or more saved for handling. Drying reduces moisture content.
- **Drying as final step:** Drying is final step in evaporation, filtration, and crystallization.

MECHANISM OF DRYING PROCESS

Drying does not mean only removal of moisture but during process, physical structure as well as the appearance must be preserved. Drying is basically governed by the principles of transport of heat and mass. When a moist solid is heated to an appropriate temperature, moisture vaporizes at or near the solid surface and the heat required for evaporating moisture from the drying product is supplied by the external drying medium, usually air or a hot gas. Drying is diffusional process in which the transfer moisture to the surrounding medium takes place by the evaporation surface moisture, as soon as some of the surface moisture vaporizes, more moisture is transported from interior of the solid to its surface. This transport of moisture within a solid take place by a variety of mechanisms depending upon the nature and type of solid and its states of aggregation. Different types of solids may have to be handled for drying crystalline, granular, beads, powders, sheets, slabs, filter-cakes etc. The mechanism of moisture transport in different solids may be broadly classified into:

- Transport by liquid or vapour diffusion
- Capillary section
- Pressure induced transport.

Free Moisture Content (FMC): The moisture content of solid more than equilibrium moisture content is referred as free moisture. During drying, only free moisture can be evaporated. The free moisture content of a solids depends upon the vapour concentration in gas.

Equilibrium Moisture Content (EMC): The moisture content of solid when it is in equilibrium with given partial pressure of vapour in gas phase is called equilibrium moisture.

Critical Moisture Content (CMC): Similarly, the moisture content at which the constant rate of drying period ends and falling rate drying period start is called critical moisture content.

Percentage Moisture Content:

$$\textbf{\% Moisture Content} = \frac{Weight\ of\ water\ in\ sample}{Weight\ of\ dry\ sample} \times 100$$

Rate of Drying:

$$\textbf{Drying Rate} = \frac{Weight\ of\ water\ in\ sample(kg)}{time(h) \times weight\ of\ dry\ solid\ (kg)}$$

Loss on Drying:

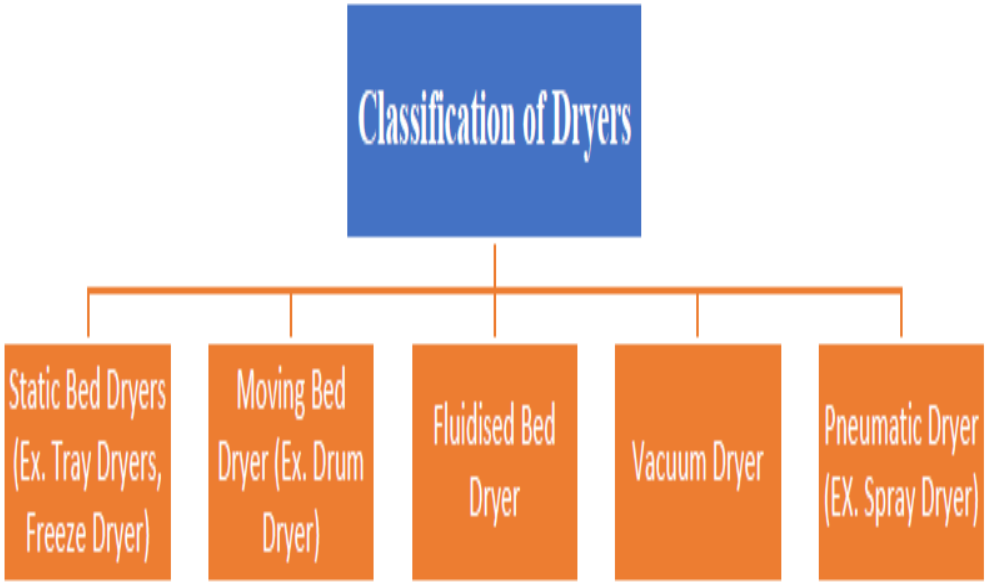
$$\textbf{Loss on Drying (\%)} = \frac{Mass\ of\ water\ in\ sample(kg)}{Total\ mass\ of\ wet\ sample(kg)} \times 100$$

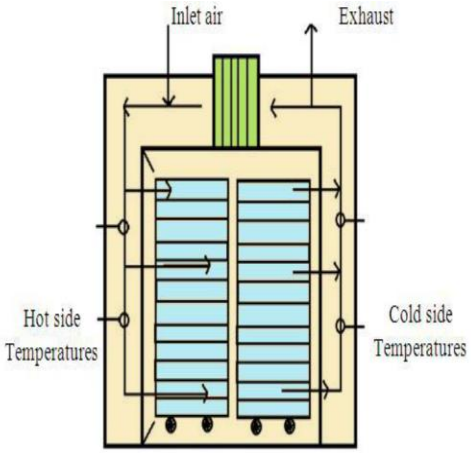
CLASSIFICATION OF DRYER

Drying equipment is classified in different ways, according to design and operating features. It can be classified based on mode of operation such as batch or continuous. In case of batch drier, the material is loaded in the drying equipment and drying proceeds for a given period of time whereas, continuous mode the material is continuously added to the dryer and dried material continuously removed. In some cases, vacuum can be used to reduce the drying temperature. Some dryers can handle almost any kind of material,

others are severely limited in the style of feed they can accept. Drying processes can also be categorized according to the physical state of the feed such as wet solid, liquid and slurry.

To reduce heat losses of the commercial dryers are insulated and hot air is recirculated to save energy. Now most of the dryers are designed as energy saving devices which recover heat from the exhaust air or automatically control the air humidity. Computer control of dryers results in less energy consumption.





TRAY DRYER:

Principle

The basic working principle of this incredible machine is the continuous circulation of hot air. In the tray dryer, moisture is removed from the solids that are placed in the tray by a forced convectional heating. The moist air is removed partially but in a simultaneous fashion.

Construction

Tray dryer is used for the best drying research in convectional process. It is a double walled cabinet with single or two doors. The gap between two walls is filled with high density fiber glass wool insulation material to avoid heat transfer. Doors are provided with gaskets. stainless steel trays are placed on the movable trolleys. Tray dryer is provided with control panel board, process timer, digital temperature controller cum indicator etc. Tray dryer is available in capacities ranging from 6, 12, 24, 48, 96, 192 trays.

Working

- In Tray dryer hot air is continuously circulated. Forced convection heating takes place to remove moisture from the solid placed in trays.
- Simultaneously the moist air is removed partially.
- Wet solid is loaded into the trays. Trays are placed in the chamber.

- Fresh air is introduced through inlet, which passes through the heaters and gets heated up.
- The hot air is circulated by means of fans at 2 to 5 meter per second.
- Turbulent flow lowers the partial vapor pressure in the atmosphere and also reduces the thickness of the air boundary layer.
- The moisture is picked up by the air. As the water evaporate from the surface, the water diffuses from the interior of the solids by the capillary action.
- These events occur in a single pass of air. The time of contact is short and amount of water picked up in a single pass is small.
- Therefore, the discharged air to the tune of 80 to 90% is circulated back through the fans. Only 10 to 20% of fresh air is introduced.
- Moist air is discharged through outlet. Thus, constant temperature and uniform air flow over the materials can be maintained for achieving uniform drying.
- In case of the wet granules as in tablet and capsules drying is continued until the desired moisture content is obtained.
- At the end of drying trays or trucks are pulled out of the chamber and taken to a tray dumping station.

Advantages

- Each batch is handled as a separate entity.
- It is more efficient in fuel consumption.
- It is operated batch wise.
- It is simple to use.
- It requires little labor costs-merely load and then unload.

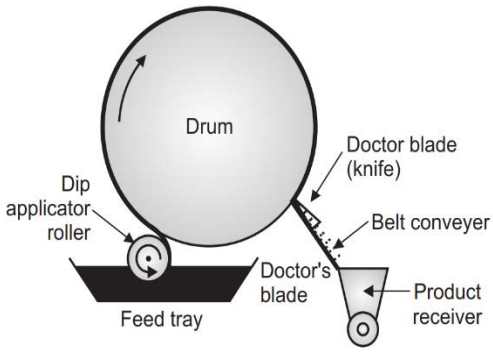
Disadvantages

- The operation is time consuming.
- It requires extra cost.
- Not suitable for oxidizable and thermolabile substances.
- It provides tendency to over dry the lower trays.
- Cleaning process is time consuming.
- Not suitable for continuous process.

Pharmaceutical Uses

- Tray dryer is used in the drying of sticky materials, e.g., Acetyl cysteine effervescent tablets.
- It is used in the drying of granular mass or crystalline materials, e.g., Calcium fluoride, Silicon dioxide.
- In the tray dryers the crude drugs, chemicals, powders and tablet granules are also dried to obtain free flowing materials, e.g.,
- Some glassware's can be dried in the tray dryers, e.g., Oral liquids, glass bottles.

DRUM DRYER



Principle

In drum drying, the heated surface is the envelop of a rotating horizontal metal cylinder. The cylinder is heated by steam condensing inside, at a pressure range of 200 to 500 kPa bringing the temperature of the cylinder wall to 120-150°C.

Construction

A drum dryer consists of one or two horizontally mounted hollow cylinder(s) or drums of about 0.75-1.5 m in diameter and 2-4 m in length, made of high-grade cast iron or stainless steel, a supporting frame, a product feeding system, a scraper, and auxiliaries. The drum is heated internally by steam, and rotated on its longitudinal axis. The external surface of the drum is polished. Liquid or slurry is placed as feed in a pan. The drum is partially dipped in pan. The spreader is used to spread liquid film evenly on roller. The rotation of the drum adjusted so that all of the liquid is fully vaporized. The drum is rotated continuously. The dried deposits can be scrapped off with the help of doctor knife.

Working

As the drum rotates, the liquid material gets adhere to external surface of drum. The liquid is spread as film on to the surface. The drying of the material is done by process of steam when passed in to the drum. By the mechanism of conduction, the heat gets transferred in to drum and drying process takes place. The material is completely dried during whole process during its revolution. The dried material is scrapped by the knife and that fall in to the bin.

Advantages

- Drying takes place in less time.
- It is suitable for thermosensitive drugs.
- It occupies less space.
- In order to reduce the temperature of drying the drum can be enclosed in a vacuum chamber.

- Rapid drying takes place due to rapid heat and mass transfer.

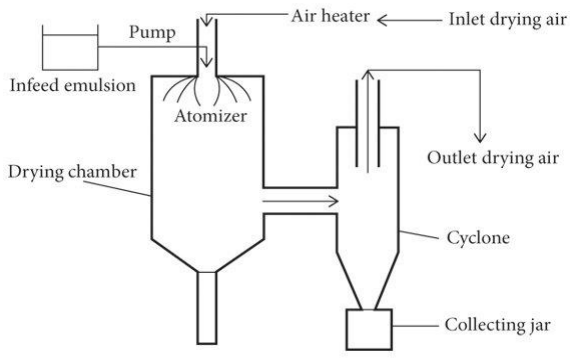
Disadvantages

- Maintenance cost is high.
- Skilled operations are essential to control thickness of film.
- It is not suitable for less solubility products.
- The operating conditions are critical. It is necessary to introduce careful control on feed rate, film thickness, speed of drum rotation and drum temperature.

Pharmaceutical Uses

- Drum dryer takes viscous liquids, slurries, suspensions, and pastes as input material to be dried and produces the output as powders or flakes.
- Drum dryers find application majorly in Food & Dairy industry and Chemical &Pharmaceutical Industries for drying various type of pasts and slurries.

SPRAY DRYER



Principle

Spray drying is an industrial process for dehydration of a liquid feed containing dissolved and/or dispersed solids, by transforming that liquid into a spray of small droplets and exposing these droplets to a flow of hot air.

Construction

A spray dryer is composed of a feed pump, atomizer, air heating unit, air dispenser, drying chamber (diameter of the drying chamber ranges between 2.5 to 9.0 m and height is 25 m or more) and also systems for exhaust air cleansing and also powder recovery/separator. The spray disk atomizer is about 300 millimeters in diameter and rotates at a speed of 3,000 to 50,000 revolutions per minutes. In the spray dryer the liquid to be dried is atomized into the good droplets, that are tossed radially into a relocating stream of warm gas.

Working

A spray dryer takes a liquid stream and separates the solute or suspension as a solid and the solvent into a vapor. The solid is usually collected in a drum or cyclone. The liquid input stream is sprayed through a nozzle into a hot vapor stream and vaporized. Solids form as moisture quickly leaves the droplets.

The three stages that occur in a spray dryer before drying is accomplished include:

- Atomization
- Spray-air mixing and moisture evaporation.
- Dry product separation from the exit air.

The nature of the final product obtained after drying in a spray dryer depends on;

- The design and operation of the spray dryer.
- The physicochemical properties of the feed.

Advantages

- Product quality and properties can be effectively controlled and maintained through the entire drying operation.
- Thermolabile products/ pharmaceuticals can be dried at atmospheric pressure and low temperature.
- Spray dryer permits high- tonnage production in continuous operation adaptable to conventional PLC control (Programmable Logic Controller) and it is relatively simple to operate.
- Feedstock in solution, slurry, emulsion, paste, and melt form can be dried if pumpable.
- Corrosion problem is minimal and the selection of materials of construction of spray dryer is simplified since the dried material comes in contact with the equipment surfaces in an anhydrous condition.
- Spray dryer produces dry powder particles of controllable particle size, shape, form, moisture content, and other specific properties irrespective of dryer capacity and heat sensitivity.
- Spray dryer handles a wide range of production rates and provides extensive flexibility in its design that is product specification are readily met through the selection of appropriate spray dryer design and its operation from a wide range of available design.
- It is energy-intensive equipment because specific heat of evaporation can be supplied in a short time. The temperature difference across the drying chamber is relatively small and an appreciable amount of heat is lost with exhaust air.

Disadvantages

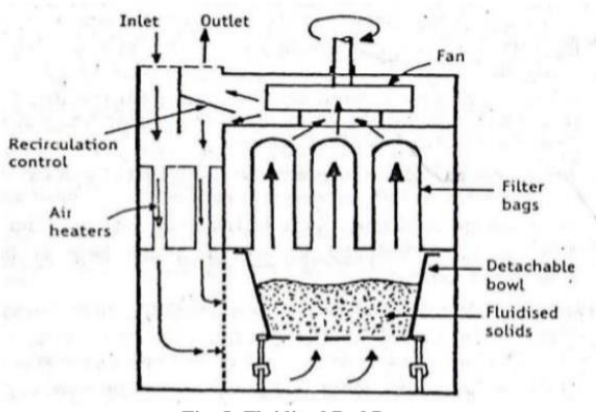
- Spray dryer is bulky and also expensive to install.
- It is difficult to clean after use.
- It has a low thermal efficiency that is a lot of heat is wasted during operation.
- Solid materials cannot be dried using spray dryers.

- Product degradation or fire hazard may result from product deposit on the drying chamber.

Pharmaceutical Uses

- Spray dryer is used in drying pharmaceuticals like penicillin, blood products, enzymes, vaccines etc.
- It is used in the production of excipients and co-processed excipients with increased flowability, compatibility, and tablet disintegration.
- To improve drug compressibility and reduce capping tendencies in crystals.
- It is equally used in the preparation of matrix microcapsule containing drug substances and a biodegradable polymer in order to obtain controlled drug release formulation.
- It is employed in enhancing solubility and dissolution rates of poorly soluble drugs by formation of pharmaceutical complexes or via the development of solid dispersion thus increasing bioavailability.
- It is used in the production of dry powder formulation/dry powder aerosol and thermolabile materials.
- Apart from its applications in the pharmaceutical industries, spray dryers also find use in; Chemical industries, Ceramic industries, Food industries, etc.
- Biochemical industries e.g. algae, fodder antibiotics, yeast extracts, enzymes, etc.
- Environmental pollution control e.g., flue gas desulfurization, black liquor from paper- making etc.

FLUIDIZED BED DRYER



Principle

The equipment works on a principle of fluidization of the feed materials. In fluidization process, hot air is introduced at high pressure through a perforated bed of moist solid particulate. The wet solids are lifted from the bottom and suspended in a stream of air.

Construction

- The dryer is made up of stainless steel or plastic.
- A detachable bowel is placed at the bottom of the dryer, which is used for charging and discharging.
- The bowel has a perforated bottom with a wire mesh support for placing materials to be dried.
- A fan is mounted in the upper part for circulating hot air.
- Fresh air inlet, prefilter and heat exchanger are connected serially to heat the air to the required temperature.
- The temperature of hot air and exit air are monitored.
- Bag filters are placed above the drying bowl for the recovery of fines.

Working

- The wet granules to be dried are placed in a detachable bowl. The bowl is inserted in the drier.
- Fresh air can pass through a prefilter, which is then heated when passing through a heat exchanger.
- Hot air flows through the bottom of the bowl.
- At the same time, fan start to rotate.
- The air speed increases gradually.
- When the velocity of air is greater than the sedimentation rate of the granules, the granules remain suspended in the gas stream.
- After specific time, a pressure point is reached in which the friction drag on a particle is equal to the force of gravity.
- The granules rise in the container due to high gas velocity of 1.5 to 7.5 meter per minute and then fall back. This state is known as fluidized state.
- The gas surround to each granule do dry them completely.
- The air comes out of the dryer passing through the filters in the bag.
- The entrained particles remain adhered to the interior surface of bags.
- Periodically bags are shaken to remove entrained particles.

Advantages

- It takes less time to complete drying as compared to other dryer.
- Drying is achieved at constant rate.
- Handling time is also short.
- It is available at different sizes with different drying capacity.
- The equipment is simple and less labor cost required.
- More thermal efficiency.
- Drying capacity is more than other dryer.

- It facilitates the drying of thermolabile substances since the contact time of drying is short.
- It is batch type or continuous type process.

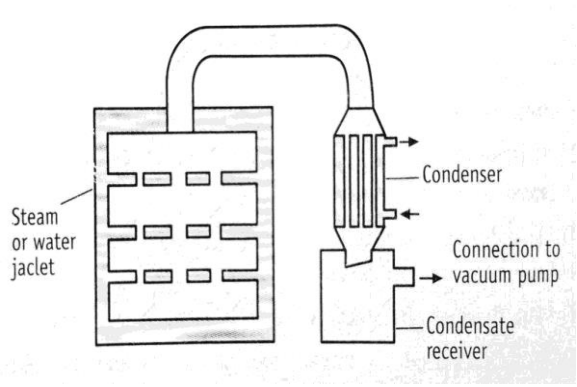
Disadvantages

- Many organic powders develop electrostatic charge during drying. To avoid this efficient electrical grounding of the dryer is essential.
- Chances of attrition of some materials resulting in production of fines.

Pharmaceutical Uses

- It is used for drying of granules in the production of tablets.
- It is used for coating of granules.
- It can be used for three operations such as mixing, granulation and drying.

VACUUM DRYER



Principle

Vacuum drying is generally used for the drying of substances which are hygroscopic and heat sensitive, and is based on the principle of creating a vacuum to decrease the chamber pressure below the vapor pressure of the water, causing it to boil. Hence, water evaporates faster. The heat transfer becomes, i.e., rate of drying enhances substantially.

Construction

The oven is divided into hollow trays which increases the surface area for heat conduction. The oven door is locked air tight and is connected to vacuum pump to reduce the pressure. The materials to be dried are kept on the trays inside the vacuum dryer and pressure is reduced by means of vacuum pump. The enclosed space is divided in to a number of portions by means of 20 hollow shelves, which are part of the jacket. These shelves provide larger surface area for conduction of heat. Over the shelves, metal trays are placed for keeping the material. The oven door can be locked tightly to give an air tight seal. The oven is connected to a vacuum pump by placing condenser in between.

Working

- The tray that are present in the dryer are used to dry the material that are placed in the shelves and the pressure is reduced to 30 to 60 Kps by vacuum pump.
- The door closes firmly and steam passes through the jacket space and the shelves.
- So, the heat transfer is carried out by the conduction mechanism.
- When evaporating under vacuum, the water is evaporated from the material at 25 - 30°C.
- The vapor goes to the condenser.
- After drying vacuum line is disconnected.
- Then the materials are collected from the tray.

Advantages

- Material handling is easy.
- Hollow shelves which are electrically heated can be used.
- It provides large surface area. So, the heat can be easily transfer through the body of the dryer and last drying action takes place.
- Hot water can be supplied through the dryer, which help in drying process at the desired temperature.

Disadvantages

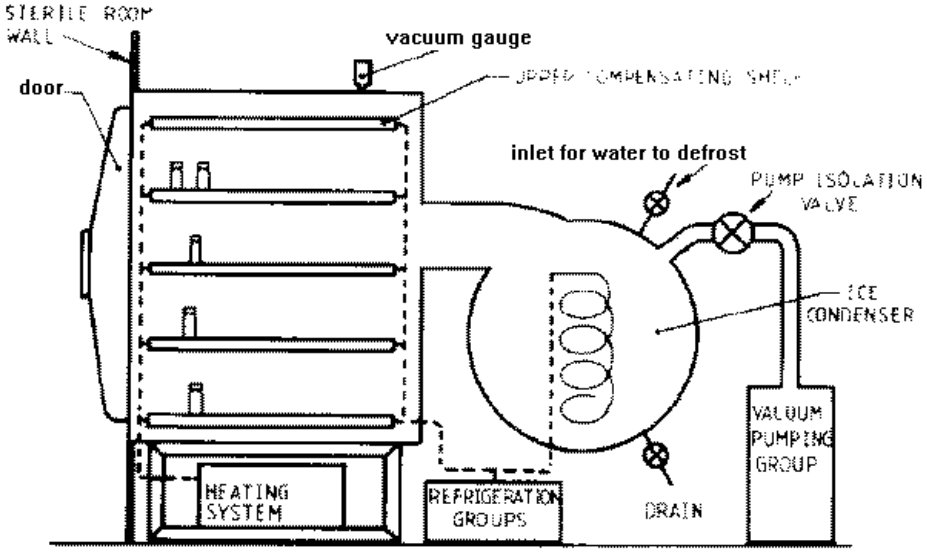
- Dryer is a batch type process.
- It has low efficiency.
- It is more expensive.
- Labor cost is too high.
- Needs high maintenance.
- There is a danger of overheating due to vacuum.

Pharmaceutical Uses

Vacuum dryer can be used for drying of following:

- Heat sensitive materials, which undergo decomposition.
- Dusty and hygroscopic material.
- Drugs containing toxic solvents. These can be separated in to closed containers.
- Feed containing valuable solvents. These are recovered by condensation.
- Drugs which are required as porous end products.
- Friable dry extracts.

FREEZE DRYER



Principle

Freeze drying or lyophilization is a drying process used to convert solutions or suspensions of labile materials into solids of sufficient stability for distribution and storage. The fundamental principle in freeze-drying is sublimation, the shift from a solid directly into a gas. Just like evaporation, sublimation occurs when a molecule gains enough energy to break free from the molecules around it. Drying is achieved by subjecting the materials to temperature and pressures below the triple point.

Construction

It consists of;

- Drying chamber in which trays are loaded.
- Heat supply in radiation source, heating coils.
- Vapor condensing or adsorption system.
- Vacuum pump or stream ejector or both.

The chamber for vacuum drying is generally designed for batch operation. It consists of shelves for keeping the material. The distance between subliming and condenser must be less than the mean path of molecules. This increases the rate of drying. The condenser consists of relatively large surface cooled by solid carbon dioxide slurred with acetone or ethanol. The temperature of condenser must be much lower than evaporated surface of frozen substance. In order to maintain this condition, the condenser surface is cleaned repeatedly.

Working

The following steps are involved in the working of freeze dryer

Pretreatment includes any method of treating the product prior to freezing. This may include concentrating the product, formulation revision decreasing a high-vapor- pressure solvent, or increasing the surface area. This reduces the actual drying by 8 to 10 times. The final product becomes more porous.

During pre-freezing, the freeze dryer works as a freezer in that no vacuum is applied. Vials, ampoules or bottle in which the aqueous solutions are packed or frozen in cold shelves (about -50°C). During this stage, cabinet is maintained at low temperature and atmospheric pressure. The normal cooling rate is about 1 to 3 kelvin per minute so that large ice crystals with relatively large holes are formed on sublimation of ice. This is also responsible for giving a porous product.

Primary drying (sublimation of ice under vacuum): In this step, the material to be dried is spread as much large surface as possible for sublimation. The temperature and pressure should be below the triple point of water, i.e., 0.0098°C and 0.533 Kilopascal, (4.58 mmHg) for the sublimation, when water alone is present. When a solution of solid is dried, the depression of freezing point of water occurs. Hence it is essential that the temperature be brought bellow the eutectic point. The pressure and temperature at which the frozen solid vaporizes without conversion to a liquid is referred to as the eutectic point. Depending on the drug substance dissolved in water, the eutectic point is determined. The usual range is from -10°C to 30°C. The condition of 1 to 8 K bellow eutectic point is sufficient.

Vacuum is applied to the tune of about 3 mmHg (0.4 Kilopascals) on the frozen sample. The temperature is linearly increased to about 30°C in a span of 2 hours.

Heat is supplied which transfers as latent heat and ice sublimes directly into vapor state. The heat controls the movement of ice layer inwards. It has to be controlled in such a manner so as to get highest possible water vapor at ice surface without melting the material. As soon as the vapor molecules are formed, these are removed. The overall driving force is the temperature difference between evaporating surface and condenser.

As the drying proceeds, the thickness of frozen layer decreases and thickness of partially dried solids increases. Primary drying stage removes easily removable moisture. During this stage, about 98% to 99% water is removed. Till traces of moisture is present in the sample. Secondary drying (removal of residual moisture under high vacuum): During this stage traces of moisture is removed. The temperature of solid is raised to as high as 50 to 60°C, but vacuum is lowered bellow that is used in primary drying (50 mmHg). The rate of drying is very low and it takes about 10 to 20 hours.

Primary drying is a top-down process with a well-defined sublimation front moving through the product as it dries. Above the ice surface interface is dried product, or "cake"; below the interface is product with ice crystals still remaining to be sublimed. After primary freeze-drying is complete and all ice has sublimed, in the area where ice has been removed, desorption of water from the cake occurs. This process is called secondary drying and has started in the primary drying phase. The product appears to be dry but the residual moisture content may be as high as 7–8%. Packing is done by replacing vacuum with inert gas, bottles and vials are closed.

Advantages

- It is suitable for drying heat sensitive products
- Freeze dried products is porous and easy to dehydrated and instantly dissolved.
- Drying takes place at very low temperature, so that enzyme action is inhibited and chemical decomposition, particularly hydrolysis, is minimized.
- Denaturation of protein does not occur.
- Loss of volatile material is less.
- Sterility can be maintained.

Disadvantages

- The process is very slow.
- Expensive process.
- It is not a general method of drying, but it is limited to certain type of valuable products that cannot be dried by any other means.
- The period of drying is high.
- The product is prone to oxidation, due to the high porosity and large surface area.

Therefore, the product must be vacuum packed or with an inert gas or in container.

Pharmaceutical Uses

- It is used in production of injection, solutions, and suspension.
- It is also used for production of blood plasma and its fractionated products, bacterial and viral cultures, antibiotics and plant extracts, steroids, vitamins and enzymes.
- Food product like mushroom, meat products can be dried by this method.
- Coffee and tea concentrates and citrus fruit juices are also dried by this method.
- Pharmaceutical companies often use freeze-drying to increase the shelf life of products, such as vaccines and other injectable.
- By removing the water from the material and sealing the material in a vial, the material can be easily stored, shipped and later reconstituted to its original form for injection.

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