FE563 ADVANCED FOOD DEHYDRATION

- **Dehydration** (or **drying**) is defined as 'the application of heat under controlled conditions to remove the majority of the water normally present in a food by **evaporation**' (or in the case of freeze drying by **sublimation**).
- The main purpose of dehydration is to extend the shelf life of foods by a reduction in water activity. This inhibits microbial growth and enzyme activity, but the processing temperature is usually insufficient to cause their inactivation.
- The term "**drying**" and "**dehydration**" are used interchangeably in process engineering.
- However, in food science and technology, the term "**drying**" is traditionally used for thermal removal of water to about **15-10 % moisture** (dry basis), which is approximately the equilibrium moisture content of dried agricultural products (e.g., fruits and grains) at ambient air conditions.
- The term "**dehydration**" is traditionally used for drying foods down to about **2-5 % moisture**, e.g., dehydrated vegetables, milk, coffee, etc.
- The dehydrated foods usually require special packaging to protect them from picking up moisture during storage.
- The term "**intermediate moisture foods**" (IMF) is used for semi-moist dried foods [fruits (apricots, grapes, ...), meat, etc.] of **20-30 % even 35 %** moisture content.
- Drying causes deterioration of both the eating quality and the nutritional value of the food.
- Examples of commercially important dried foods are coffee, milk, raisins, and other fruits, pasta, flours (including bakery mixes), beans, nuts, breakfast cereals, tea and spices.

➢ There are a large number of factors that control the rate at which foods dry, which can be grouped into the following categories

- those related to the processing conditions (temperature, air velocity, properties of air, etc.)
- those related to the nature of the food (composition of food, semi-solid, slurry, paste, etc.)
- those related to the drier design (batch, continuous, air dryers, freeze dryers, drum dryers, etc.)

Drying using heated air

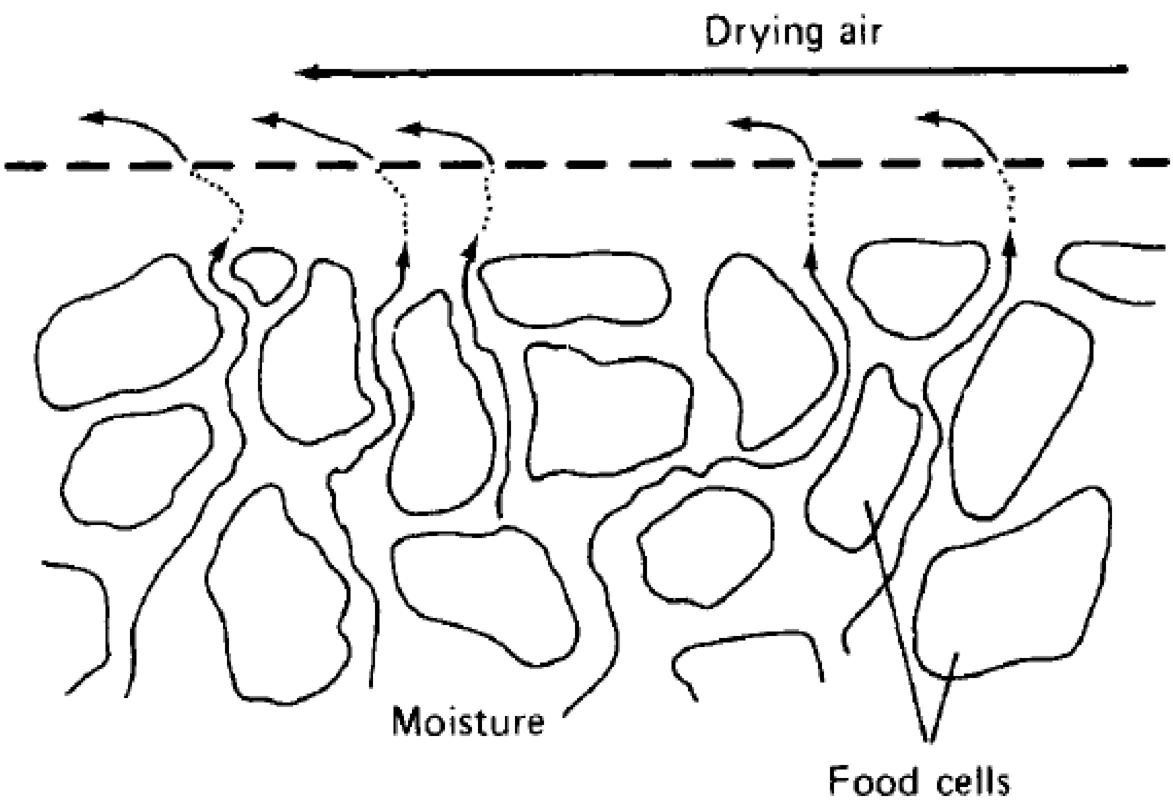
- There are three inter-related factors that control the capacity of air to remove moisture from a food:

1. the amount of water vapor already carried by the air
2. the air temperature
3. the amount of air that passes over the food.

- The amount of water vapour in air is expressed as either *absolute humidity* or *relative humidity* (RH) (in per cent).
- Psychrometry is the study of inter-related properties of air–water vapour systems.
- Heat from drying air is absorbed by food and provides the latent heat needed to evaporate water from the surface. The difference between the *dry-bulb* temperature and the *wet-bulb temperature* is used to find the relative humidity of air on the psychrometric chart
- Adiabatic cooling lines are the parallel straight lines sloping across the chart.

Mechanism of drying

- The third factor that controls the rate of drying, in addition to air temperature and humidity, is the air velocity. When hot air is blown over a wet food, water vapor diffuses through a boundary film of air surrounding the food and is carried away by the moving air
- A water vapour pressure gradient is established from the moist interior of the food to the dry air. This gradient provides the 'driving force' for water removal from the food.
- The boundary film acts as a barrier to both heat transfer and water vapor removal during drying. **The thickness of the film** is determined primarily by the **air velocity**; if the **velocity is low**, the boundary **film is thicker** and this **reduces both the heat transfer coefficient** and the rate of **removal of water** vapor. Water vapor leaves the surface of the food and increases the humidity of the surrounding air, to cause a reduction in the water vapour pressure gradient and hence the rate of drying. Therefore the **faster the air**, the **thinner the boundary film** and hence the **faster the rate of drying**.



Factors affecting on drying

- The *composition and structure* of the food has an influence on the mechanism of moisture removal. For example, the orientation of fibres in vegetables and protein strands in meat allow more rapid moisture movement along their length than across the structure.
- The *amount of food* placed into a drier in relation to its capacity (in a given drier, faster drying is achieved with smaller quantities of food).

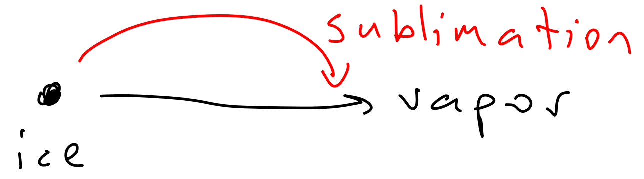
Drying using heated surfaces

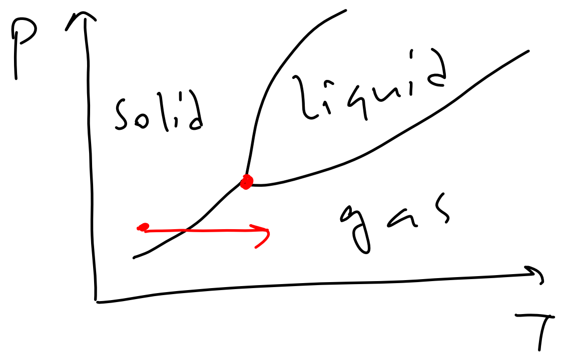
- Slurries of food are deposited on a heated steel drum. Heat is conducted from the hot surface, through the food, and moisture is evaporated from the exposed surface. The **main resistance to heat transfer is the thermal conductivity of the food**.
- Additional resistance arises if the partly dried food lifts off the hot surface, forming a barrier layer of air between the food and the drum.

Drying is a complex process involving simultaneous heat, mass and momentum transfer.

In most cases, drying involves the application of thermal energy which causes to evaporate into the vapor phase.

Exception: freeze drying.





Foods are dried commercially;

- starting either from their natural state; fruits, vegetables, milk, spices, etc..

OR

- after processing; instant coffee, whey, soup mixes.

Reasons for Drying a Food

1) preserve the product and extend its shelf-life. How?

Microorganisms that cause food spoilage and decay cannot grow and multiply in the absence of water.

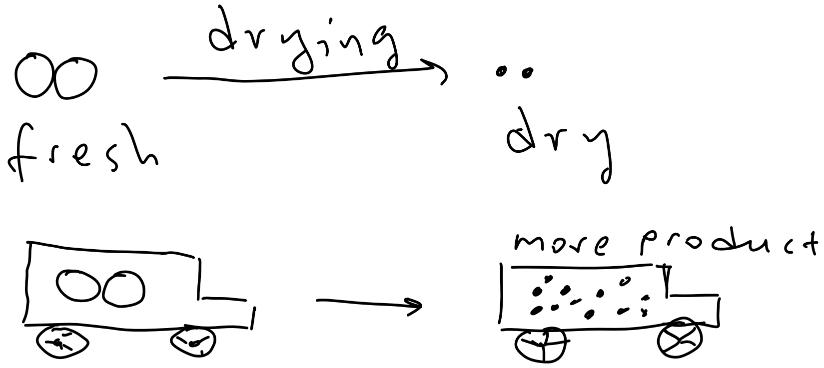
Also, many enzymes that cause chemical changes in food and other biological materials cannot function without water. When the water content is reduced below about 10% by wt, the M.O. are not active.

However, it is usually necessary to lower the moisture content below 5% in foods to preserve flavor and nutrition.

2) obtain desired physical form (e.g., powder, flakes, granules)

3) obtain desired color, flavor or texture.

4) reduce volume or weight for transportation



5) produce new products which would not otherwise be feasible.

Basic Dryer Types

(based on the mode of heat input)

1) convection (direct): this accounts 90% of dehydrated foods.
2) conduction (contact)
3) radiative (Infrared)
4) dielectric (e.g., microwave) heating
5) combinations of one or more of these modes.

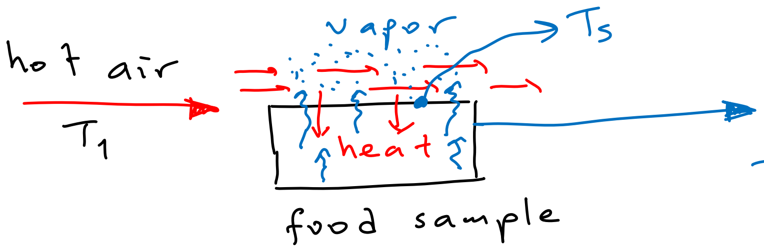
⊗ These dryers may be batch or continuous.

Spray, rotary and drum dryers can only be operated in the continuous mode. However, the other dryers can operate as batch or continuous.

⊗ The size of dryers can be small (up to 50 kg/h), medium (50 - 1000 kg/h) and large (above 1000 kg/h).

Humidity and Humidity Chart

A majority of dryers in the food industry are of the direct (or convective) type.
i.e., hot air is used both to supply the heat for evaporation and to carry away the evaporated moisture from the product.



saturated air, T_2

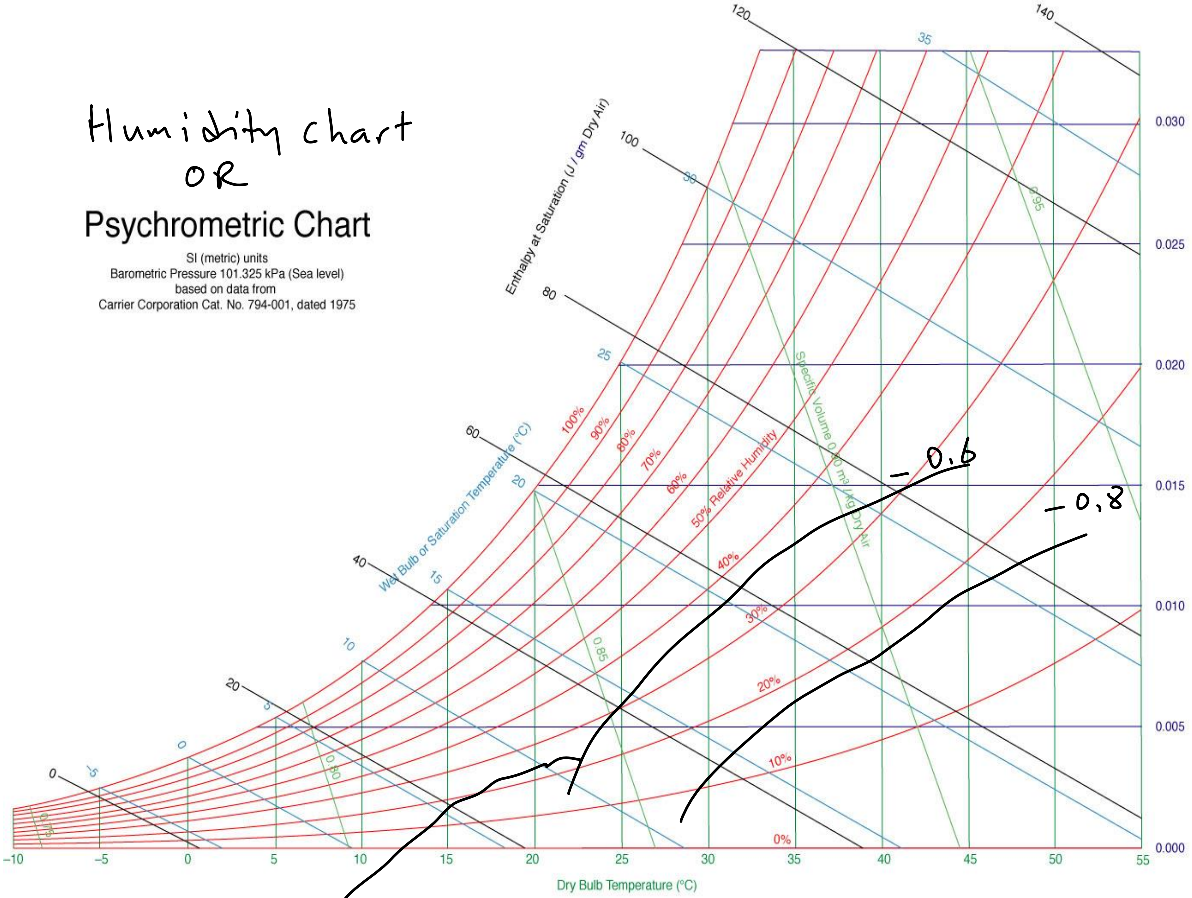
$T_2 = T_s = T_{wb}$

↙ surface temperature is equal to saturation temp.

here; – air is humidified } in a well
– " " cooled; $T_1 > T_2$ } insulated dryer.

So, the hygrothermal properties of humid air are required for the design calculations of dryers. These properties are provided by humidity charts. Humidity charts show the relationships between the T and absolute humidity of humid air at 1 atm total pressure.

Humidity chart
OR



H: absolute humidity.

$H = \frac{kg\ H_2O}{kg\ DA}$

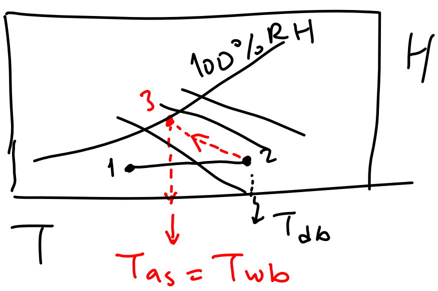
Temperature

enthalpy deviations (kJ/kg DA)

Definition of Terms Employed in Psychrometry and Drying:

Adiabatic Saturation Temperature (T_{as}):

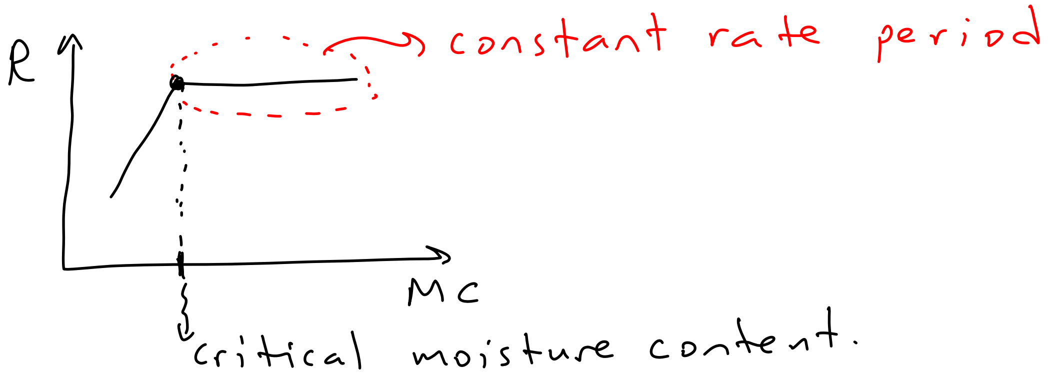
Equilibrium gas T reached by unsaturated gas and vaporizing liquid under adiabatic conditions (for the air-water system only, it is equal to the wet bulb temperature, T_{wb}).



Bound Moisture: Liquid physically and/or chemically bound to a solid matrix so as to exert a vapor pressure lower than that of pure liquid at the same temperature.

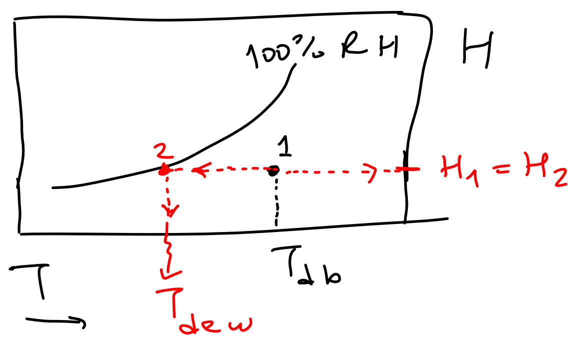
Constant Rate Drying Period (R_c): Under constant drying conditions, drying period when evaporation rate per unit drying area is constant (when the surface moisture is removed).

R: drying rate, MC: moisture content ⇒



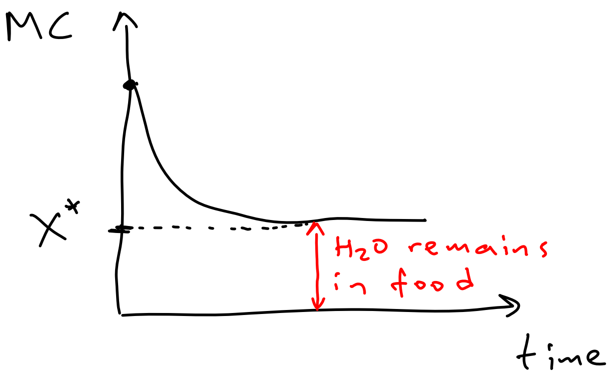
Critical Moisture Content (X_c): Moisture content at which the constant drying rate first begins to drop.

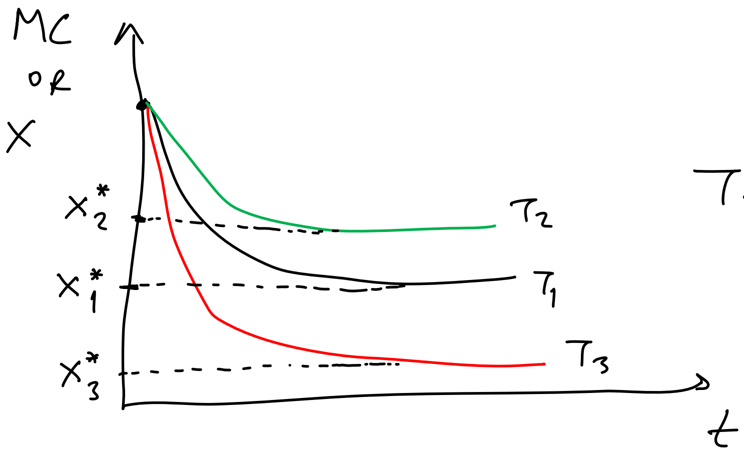
Dew Point (T_{dew}): Temperature at which a given unsaturated air-vapor mixture becomes saturated.



Dry Bulb Temp. (T_{db}): Temperature measured by a dry thermometer immersed in vapor-gas(air) mixture. It is the T of heated air to be used in drying operation.

Equilibrium Moisture Content (X^*): At a given T and P, the moisture content of a moist solid in equilibrium with the gas-vapor mixture.





$T_3 > T_1 > T_2$

⊛ If %RH (i.e., a_w) of surrounding air = a_w of food that we are drying ⇒ no further drying occurs.

i.e., $\frac{dX}{dt} \cong 0$ at X^*

<u>Note that:</u> $a_w = \frac{\%RH}{100}$