

DRYING: PRINCIPLES AND THEORY

OBJECTIVES OF DRYING

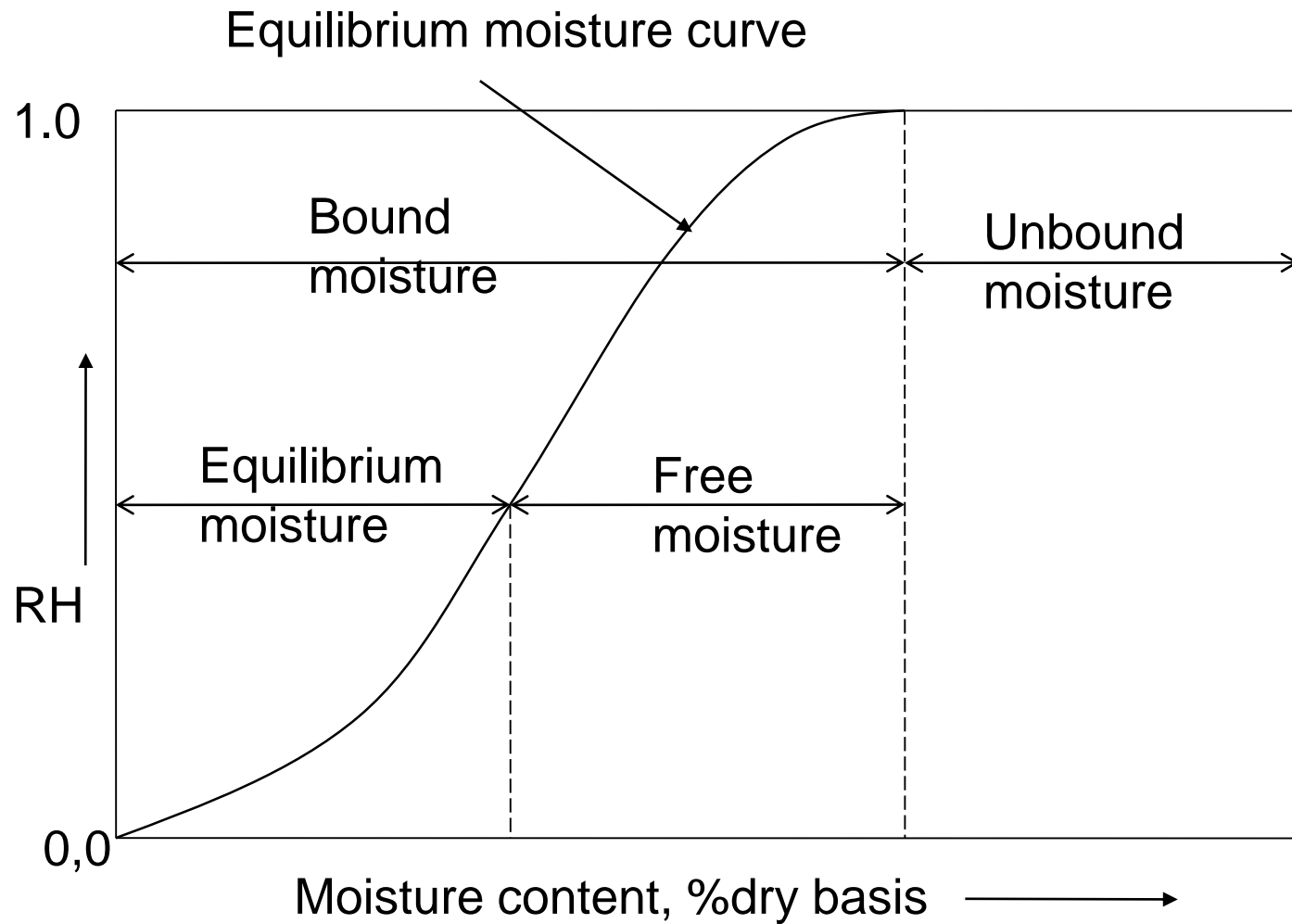
- To preserve perishable raw food commodity against deterioration or spoilage by reducing moisture content and thus by reducing water activity.
- To reduce the cost and difficulty of packaging, handling, transportation and storage by converting the material into a dry solid, thus reducing its weight and in most cases volume.

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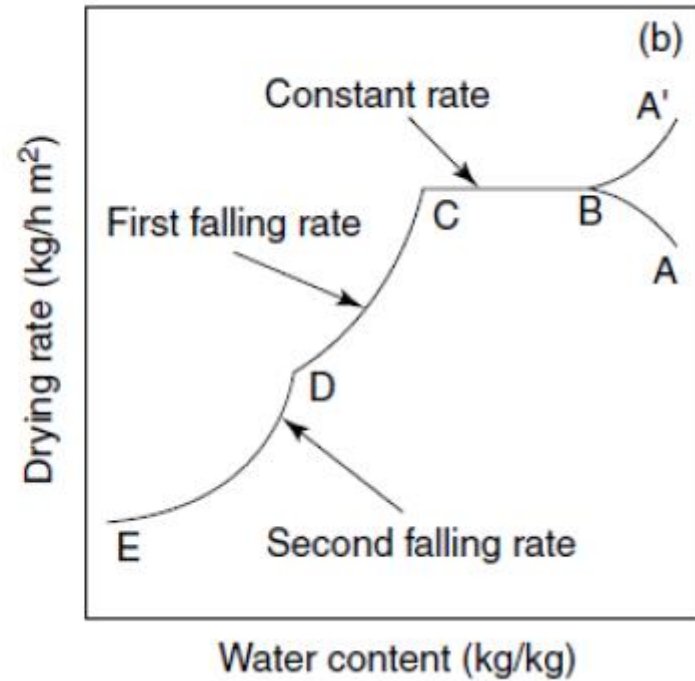
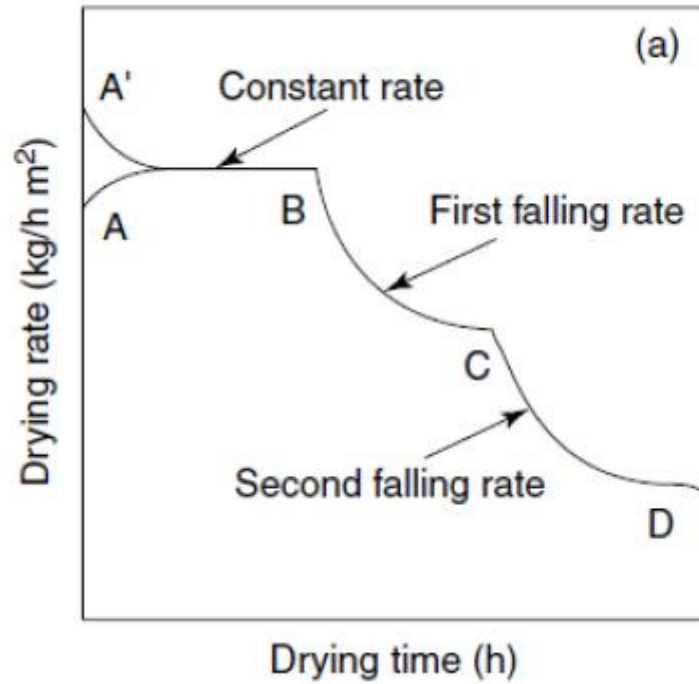
- Moisture content dry basis and wet basis
- Absorbed/ Adsorbed moisture

Equilibrium moisture / Free moisture Bound moisture/ Unbound moisture



BASIC DRYING THEORY

- Drying is a complex operation involving transient transfer of heat and mass transfer.
- Sensible and latent heat must be transferred to the food to cause the water to evaporate
- **Physical changes** that may occur include shrinkage, puffing, crystallization, and glass transitions.
- In some cases, desirable or undesirable chemical or biochemical reactions may occur, leading to changes in color, texture, odor, or other properties of the solid product.



Typical drying rate curves: (a) drying rate versus drying time and (b) drying rate versus water content

- Drying curve usually plots the drying rate versus drying time or moisture contents.
- Three major stages of drying can be observed in the drying curve.
- **Transient early stage**, during which the product is heating up (transient period)
- **Constant rate period**, in which moisture is comparatively easy to remove
- **Falling rate period**, in which moisture is bound or held within the solid matrix

Constant rate:

- Section B to C of the curve, known as the constant rate periods, represents removal of unbound water from the product.
- The surface of the product is very wet and the water activity is equal to one.
- In the constant-rate period, the water is being evaporated effectively as a free water surface.
- The rate of removal of water can then be related to the rate of heat transfer, if there is no change in the temperature of the material and therefore all heat energy transferred to it must result in evaporation of water.

Falling rate:

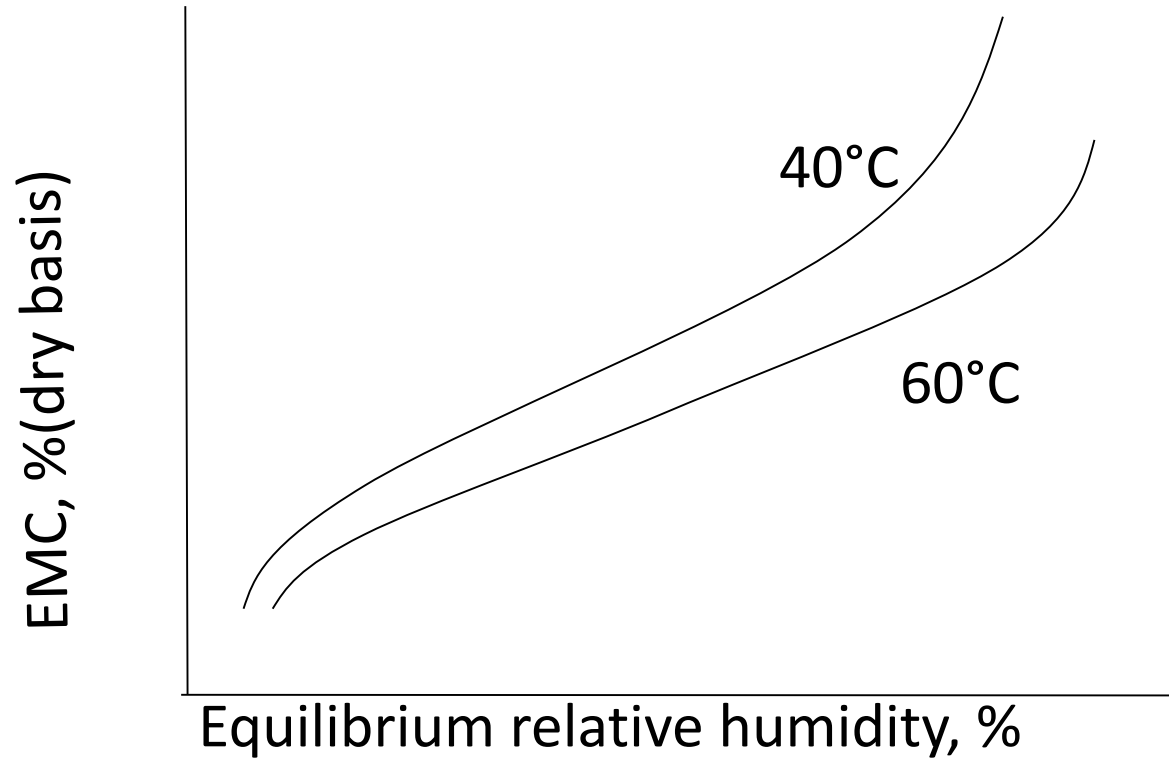
- The falling rate period (from point C) is reached when the drying rate starts to decrease, and the surface water activity falls to less than one.
- At this point there is not enough water on the surface to maintain a water activity value of one.
- The rate of drying is governed by the internal flow of liquid or vapor.
- The falling rate period can be divided into two steps.
 - ✓ First falling drying rate (C to D)
 - ✓ Second falling drying rate (D to E)

Falling rate:

- A first falling drying rate occurs when wetted spots in the surface continually diminish until the surface is dried (Point D).
- Second falling rate period begins at point D when the surface is completely dry and until the EMC is reached.

Transport of moisture within the solid may occur by any one or more of the following mechanisms of mass transfer:

- ✓ Capillary flow
- ✓ Liquid diffusion, if the wet solid is at a temperature below the boiling point of the liquid
- ✓ Vapor diffusion, if the liquid vaporizes within material
- ✓ Knudsen diffusion, if drying takes place at very low temperatures and pressures, e.g., in freeze drying
- ✓ Surface diffusion (possible although not proven)
- ✓ Thermal diffusion
- ✓ Hydrostatic pressure differences, when internal vaporization rates exceed the rate of vapor transport through the solid to the surroundings
- Combinations of the above mechanisms



Equilibrium moisture curve at two temperatures

Water activity

Water activity is defined as the chemical potential of the water present in a food- its ability to participate in chemical reactions. It is denoted as a_w .

Ice at 0, -10, -20 and -50°C have the water activities of 1.00, 0.91, 0.82 and 0.62, respectively.

Remember that all of them have 100% moisture.

Mathematically, water activity is given as the ratio of the vapour pressure of water in a solution (p_s) to the vapour pressure of pure water (p_w).

$$a_w = p_s/p_w$$

Water activity

Various parameters affecting water activity

Temperature,

pH,

Oxygen and CO₂ in the system

Chemical preservatives added to the commodity

To inhibit most of the bacteria : $a_w < 0.9$

To inhibit most of the yeasts : $a_w < 0.8$

To inhibit most of the fungi : $a_w < 0.7$

To inhibit most of the microorganisms: $a_w < 0.6$.

To avoid other deteriorative reactions, $a_w < 0.3$.

Water activity

Norrish equation (for a_w at high moisture contents)

$$\log \frac{a_w}{x_w} = -k(1 - x_w)^2$$

where,

x_w = mole fraction of water in the food / solution.

The values of constant k for various solutes in Norrish's eqn for water activity of solutions have been found out. For example

$k_{\text{sucrose}} = 2.7$ and $k_{\text{glucose/ fructose/ invertase}} = 0.7$

Water activity

Brunauer-Emmett-Teller (BET) equation (For water activity at low moisture contents, a_w between 0 to 0.45 or so) :

$$\frac{a_w}{M(1 - a_w)} = \frac{1}{M_1 C} + \frac{C - 1}{M_1 C} a_w$$

where,

M is the moisture of the commodity (per cent dry basis),

M_1 is the moisture (per cent dry basis) of a monomolecular layer (moisture content at which the water molecules coat the surface of the solid particles in a mono-molecular layer),

C is a constant (temperature dependent and related to heat of adsorption).

Thank You