DEFINITIONS

• Water reduction from the product is often called drying or dehydration. However, drying and dehydration have a different meaning.
• Drying: is to remove or reduce the water content of the material until it reaches the normal equilibrium with a moisture content of the surrounding air or when water content of materials are safe from enzyme activity and fungi, bacteria, or insects attack. Various materials generally occurs at 12-14% moisture content.
• Dehydration is the excessive lost or the reduction of moisture content deeply into bone dry. Bone dry conditions is zero (0) moisture content.

THE BENEFIT OF DRYING

• Drying is done to secure the economic value of products for the following reasons:
  – Harvesting can be done earlier in a high moisture content without damage and facilitate following processes such as peeling and threshing. For example, in maize, rice, or other grains.
  – The product can be stored a long time without damage.
  – Seed vigor can be maintained for a long time.
  – Handling product easier for example in cotton and maize
  – Products can be produced with high economic value such as the tobacco, dried fruit and vegetables
  – Waste can be converted into useful products, such as animal feed.

Advantages of Drying Fruits and Vegetables:
1. Reduced product weight ¼ to 1/9 so reduce transportation costs.
2. The need of storage is smaller because of product volume reduced
3. Products can be durable without preservatives.
4. The concentration of nutrients per unit of weight is very high.
5. Processing costs will be lower.
**MOISTURE CONTENT**

- Moisture content is often expressed based on wet weight (wet basis) or based on the dry weight (dry basis).
- Moisture content wet basis expressed as a percentage of the wet weight of the material (g water/100 g sample): \( m = \frac{100W_m}{W_m + W_d} \) where \( m \): wet basis moisture content, \( W_m \): water weight and \( W_d \): bone dry weight of material. A simple way to calculate is: \( m = \frac{WW-DW}{WW} \times 100\% \), \( WW \): wet weight, and \( DW \): dry weight.
- Dry basis moisture content is the ratio of water to the dry weight of material: \( M = \frac{100m}{100-m} \). A simple way to calculate is : \( (WW-DW) / WW\).
- Moisture content wet basis is often not appropriate when used in drying because both the moisture content and the basis weight changes in the drying process.

**MEASURING MOISTURE CONTENT**

- Direct method (using oven): the water is vaporized then wet weight and dry weight were weighed. The length time and temperature of drying until a constant moisture content varied between materials:
  - Grains: 204-212°F for 5 hours with a vacuum oven, or 271-279°F for 2 hours with a regular oven
  - Dried fruit: 158°F with a vacuum oven.
- Indirect method: based on the diversity of resistance or electrical capacity of the material in relation to the water content of materials which then can be calibrated into water content of the material. This tool is generally called a moisture tester.

**EQUILIBRIUM MOISTURE CONTENT**

- Agricultural products containing materials that absorb water so has varied water vapor pressure according to the different levels of the water or to the type of material types. The ratio of saturated water vapor pressure at the temperature called to as the equilibrium relative humidity. Curve between equilibrium relative humidity with water content is called equilibrium moisture content.
- Curve equilibrium moisture content is expressed in the equation: \( 1-r_h = e^{-cT}M_e^n \), with \( r_h \): equilibrium relative humidity, \( M_e \): equilibrium water content, \( T \): temperature, \( c \) and \( n \): constants. Examples of constants: corn: \( c = 1.10 \times 10^{-6} \) and \( n=1.90 \), Soybeans: \( c=3.20 \times 10^{-5} \) \( n=1.52 \).
- Equilibrium properties is important in drying and storage. If the \( rh \) air > equilibrium moisture content of materials, material moisture content will increase and vice versa.

**Formulas used in calculation of refraction:**

- Kg of removed water per kg of wet material:
  \[ \frac{E}{F} = \frac{m_1-m_2}{100-m_2} \text{ or } \frac{E}{F} = \frac{M_1-M_2}{M_1+100} \]

- Kg of removed water from kg of dry material:
  \[ \frac{E}{P} = \frac{m_1-m_2}{100-m_1} \text{ or } \frac{E}{P} = \frac{M_1-M_2}{M_2+100} \]

- Kg of wet product produce kg dry product:
  \[ \frac{F}{P} = \frac{100-m_2}{100-m_1} \text{ or } \frac{F}{P} = \frac{M_1+100}{M_2+100} \]

- Kg of dried product per kg of wet product:
  \[ \frac{P}{F} = \frac{100-m_1}{100-m_2} \text{ or } \frac{P}{F} = \frac{M_2+100}{M_1+100} \]

- Kg of removed water per kg of dried product:
  \[ \frac{E}{W_d} = \frac{100m_1-m_2}{100-m_1}(100-m_2) \text{ or } \frac{E}{W_d} = \frac{M_1-M_2}{M_2+100}(M_2+100) \]

Where \( F \): wet weight (\( W_m+W_d \)), \( E \): the weight of evaporated water, \( P \): weight after drying, \( W_d \): dry weight of material.
DRYING MECHANISM

- In the drying mechanism can be divided into two: constant rate period and falling rate period.
  - **Constant rate period**: on the material contains a lot of water or water on the surface material that can be evaporated easily. Drying the water content is going to increase constant rate period. Constant rate period stops when free water on surface has been depleted evaporated.
  - **Falling rate period**: generally occurs in agricultural materials. Drying process in falling rate period consists of the movement of water vapor from inner material to the surface and water evaporation from the surface.

Relation with this in drying agricultural products can not be directly applied to high temperature and needs tempering (stop drying a while) in order to perfectly drying but did not over dried.

- At drying time, the product does not lose water constantly, even in conditions with constant heat. For example in the first 2 hours can dry 90%, there could be 2 hours later could not finish drying the rest (10%). It is as seen on curve of drying rate vs drying time.
Drying procedure and the type of equipment used depends on the material resistance to temperature, moisture, pressure, and the flow rate of materials. Tobacco, for example, are sensitive to humidity and temperature, and is not resistant to pressure, and do not have the ability to flow. Otherwise of corn, resistant to temperature, pressure, humidity, and material flowed easily.

Factors that affect the drying rate of horticultural products:
- Composition of raw materials
- The size, shape, and composition of the accumulation procedure
- Temperature, relative humidity, and air flow
- Pressure and heat transfer to the product surface.

- Pre-drying treatment: includes preparation of raw materials and color preservation. Preparation of raw materials include: sorting (size, maturity, and performance), washing, cutting and blanching (boiling to stop the enzymatic reaction). Preservation of color is done with sulfuring (SO2), for example to prevent browning.
DRYING SYSTEMS

- Conduction / Adiabatic / Indirect Drying
  System: Direct contact between the product with a hot surface or hot particles.
- Convection Drying System: air heated to a certain level and then air as a medium for transferring heat to the product.
- Radiation Systems: products become dry because it absorbs energy from a source that emit electromagnetic radiation. The absorbed energy is then converted into heat to evaporate water from the these cells products.

DRYING METHOD

- Application of hot air (convective or direct drying). Air heating increases the driving force for heat transfer and accelerates drying. It also reduces air relative humidity, further increasing the driving force for drying.
- In the falling rate period, as moisture content falls, the solids heat up and the higher temperatures speed up diffusion of water from the interior of the solid to the surface.

- However, product quality considerations limit the applicable rise to air temperature. Excessively hot air can almost completely dehydrate the solid surface, so that its pores shrink and almost close, leading to crust formation or "case hardening".

- Indirect or contact drying (heating through a hot wall), as drum drying, vacuum drying. higher wall temperatures will speed up drying but this is limited by product degradation or case-hardening. Drum drying belongs in this category.
- Dielectric drying (radiofrequency or microwaves being absorbed inside the material). It may be used to assist air drying or vacuum drying.
- Freeze drying or lyophilization is a drying method where the solvent 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 increasingly applied to dry foods, beyond its already classical pharmaceutical or medical applications. It keeps biological properties of proteins, and retains vitamins and bioactive compounds. Pressure can be reduced by a high vacuum pump (though freeze drying at atmospheric pressure is possible in dry air). If using a 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.

Batch or bin dryer.
- The dried material is placed in batch or containers. This drying system is simple, rather cheap, and can be used as a storage.
- The dried material should have a resistance to pressure or not easily broken.
Some types of bath drying system: the heat source from below, sides, slope area, and central.
The modification is aimed to ensure drying uniformity and ease of loading-unloading product.

Continuous Gravity Flow driers:
- Shaped like silos, usually for drying materials / products in granules shape.
- Wet material is inserted through a hoper from above, then move down with gravity and lifted up again by bucket elevators.
- While the material moves downward, the hot air discharged from the silo to penetrate the material.
Solar energy Dryer

- Solar energy is collected in the drying unit which has adequate evaporation ventilation hole to dispose of water vapor. The temperature in this tool is about 20-30 degrees higher than in the open area with sunlight so that drying time is shorter. The weakness of this tool is only dependent on the weather.

Tray Drier

- The dried product is spread thinly on the shelves dryers.
- Heating can be derived from the air flow across the tray, or the conduction from the heating tray, or radiation from a hot surface, but generally by convection with the flow of hot air.
- Airflow generally ranges from 5 to 5 m/s/m² across the tray and dispose of water vapor at the same time.
- This type of dryer for small scale around 1-20 t/day.
Tunnel Dryer

- Is one of the commercial dryers that are flexible, efficient, and widely used.
Figure 7.14. Typical schematic arrangement of a spray dryer.