Principles of Drying and Dehydration

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Drying

Drying is one of the age-old techniques for preservation and value addition of food products. Generally, it means removal of moisture from food products by means of evaporation. It is a simultaneous heat and mass transfer process to yield a dried product. It is aimed at lowering the water content of foodstuff, thereby arresting the growth of microbes, action of enzymes and other autolytic chemical reactions (Naidu *et al.,* 2016). This preservation technique is predominately used for food materials which are regarded as "highly perishable" like fruits and vegetables, milk and fish. The benefits of drying includes extended shelf-life, lower storage space, reduced packaging requirements, lower handling and transportation costs, off seasonal availability and importantly diversified product for the consumers (Bonaui *et al.,* 1996). Dehydration is a term intermittently used for drying, however dehydration is typically used to refer a material which is dried to level of bone-dry condition *i.e* in addition to the removal of unbound moisture, part of the bound moisture is also removed in this process (Figure 1).

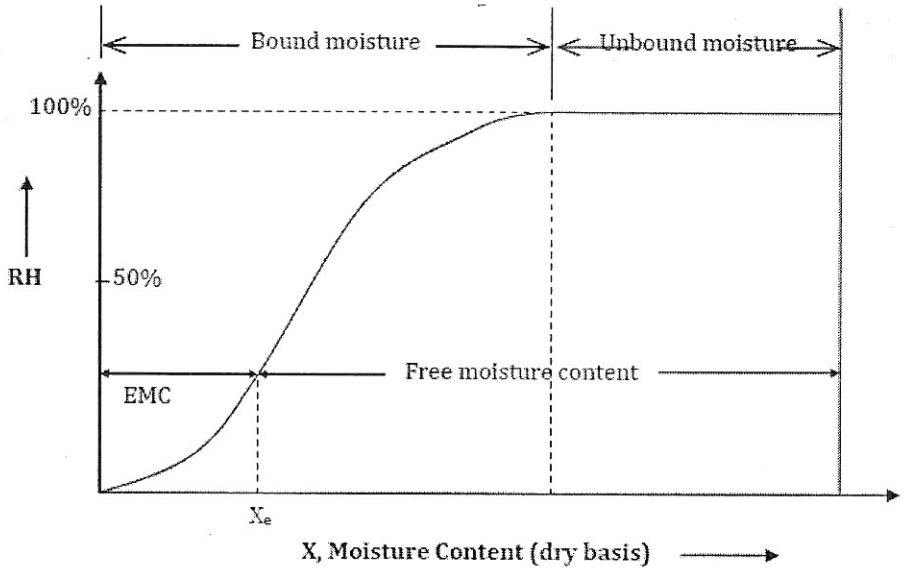

Fig 1. Relationship between EMC & RH of the food product
(adapted from Jangam et al. 2010)

Basic terminologies used in drying

Concepts	Definition
Bound moisture	Moisture physically and/or chemically bound to solid matrix, thus exerting water vapor pressure lower than the free water at the same temperature
Constant rate drying period	The amount of moisture removed per unit area per unit time is equal to the evaporation of moisture from free water surface under constant drying conditions
Dew point	The temperature to which unsaturated air-vapor mixture to be cooled to become saturated
Dry bulb temperature	Temperature measured by a dry thermometer immersed in vapor-air mixture
Equilibrium moisture content	At a given temperature and relative humidity, the moisture content of moist solid in equilibrium with the gas-vapor mixture
Critical moisture content	The moisture content at which the drying rate first begins to fall during constant rate drying period
Falling rate period	Drying period under constant drying conditions during which the drying rate falls continuously with time
Free moisture	Moisture content in excess of the equilibrium moisture content at given air humidity and temperature
Specific heat	The amount of heat required to raise the temperature of unit mass of dry air and its associated vapor through one degree (J kg-1 K-1)
Absolute humidity	Mass of water vapor per unit mass of dry air (kg kg-1)
Relative humidity	Ratio of partial pressure of water vapor in gas-vapor mixture to equilibrium vapor pressure at the same temperature (%)
Unbound moisture	Moisture in solid which exerts vapor pressure same as that of frre liquid at the same temperature
Water activity	Ratio of vapor pressure exerted by water in the product to that of pure water at the same temperature
Wet bulb temperature	Temperature measured by a dry thermometer attached with wet cloth. It is the temperature measured when the water holding capacity of air is equal to the amount of moisture released to air. i.e. temperature of drying air during constant rate drying period.

Factors affecting the drying process

There are numerous factors which affects the drying process. Few are related to the nature of the product and others pertain to design aspects of the dryer.

☐ **Properties of the Product**

- Shape, size/thickness of the material
- Composition, structure, and porosity - season & variety
- Initial moisture content
- Surface area & characteristics

☐ **Dryer Properties**

- Type of dryer & design features
- Air temperature, relative humidity & air velocity
- Drying time
- Volumetric air flowrate - pattern and uniformity
- Variations in weather conditions

Fish drying

Use of open-air sun drying assisted by natural wind flow as a method of fish preservation by primitive societies is recorded in history. However, open sun drying of fish has few draw backs which includes poor product quality, higher microbial contamination and dependence of weather conditions for drying (Bala & Mondol, 2001). In later stages, drying developed into completely controlled process in which drying air temperature, relative humidity and air velocity is maintained at optimum level. In order to maintain the required drying conditions in the latest fish drying methods, external energy input is necessary. The fish drying process is slightly different from other food materials due to its gel like behaviour until considerable reduction of water. In fish drying substantial amount of shrinkage takes place in addition to the other irreversible changes.

Generally, air drying of fish takes place in two distinct stages (Valle & Nickerson, 1968). First stage of drying is called as constant rate drying period in which simultaneous heat and mass transfer takes place under steady state conditions (Figure 2). In this stage, the moisture carrying capacity of the drying air is completed utilized. However, only the surface moisture of fish is removed in this stage and amount of moisture removal also depends on the given drying conditions i.e. drying air temperature, relative humidity of air etc. Second stage of drying is referred as falling rate drying period in which simultaneous state heat and mass transfer takes place under unsteady state conditions. That means the moisture carrying capacity of the drying air is not fully met by the product (Jain & Pathare, 2007). In this stage, the rate

of moisture removal is less and it depends on the fish moisture. In this stage, two different phases occur *i.e* unsaturated surface drying, and moisture movement from internal tissues to surface by diffusion process. Darvishi *et al.* (2013) reported that the entire sardine fish drying occurred under falling rate drying period and governed by principle of moisture diffusion.

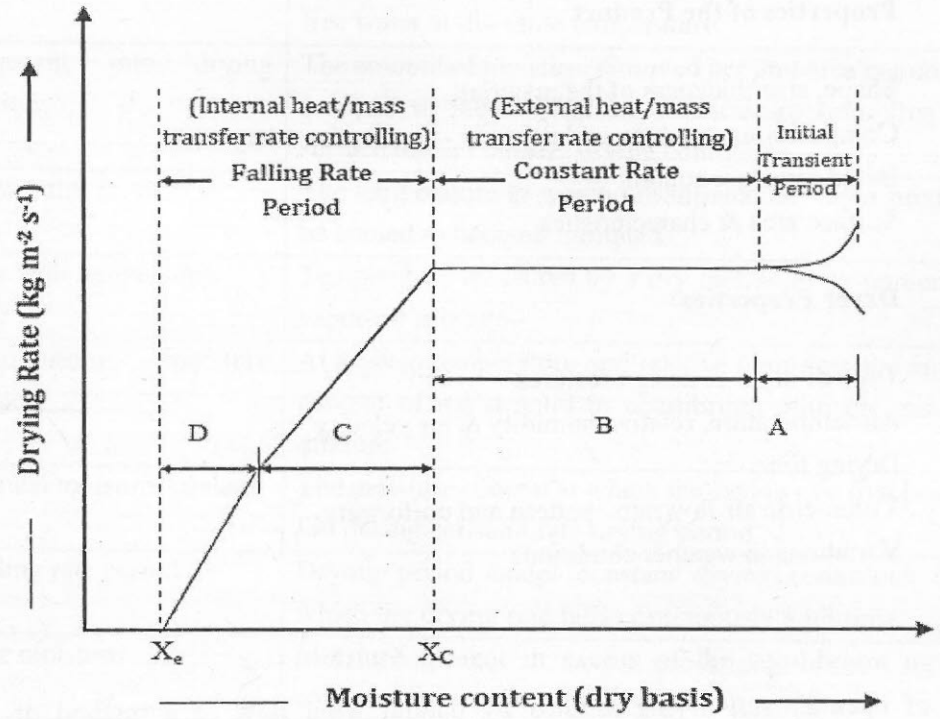

Fig 2. Drying rate curve of the food product under constant drying conditions (adapted from Jangam et al. 2010)

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