Drying Time Predictions

Constant Rate Period

The rate of moisture removal from a product during the constant rate period is described by

(1)

During the constant rate period, the thermal energy is transferred to the product due to convective heat transfer from the hot air to the product, as

(2)

Note that during the constant rate period, the product temperature remains at the wet bulb temperature of the surrounding air.

The following mass transfer expression describes the moisture transfer during the constant rate period

$$\dot{m}_c = \frac{k_m A M_w P}{0.622 R_u T_A}(W_S - W_a) \tag{3}$$

The time for constant rate drying period is obtained from substituting (1) in (3)

$$t_c = \frac{0.622 R T_A (w_0 - w_c)}{k_m A M_w P (W_s - W_a)} \tag{4}$$

The constant rate drying period is inversely proportional to the gradient of humidity ratios at the product surface and in the heated air.

<u>An alternative approach</u> to determine the time for drying during constant rate period is based on thermal energy transfer, the thermal energy causes transfer of water to vapors, or,

(5)

By combining (5) and (2)

$$\dot{m}_c = \frac{w_0 - w_c}{t_c} = \frac{hA}{H_L}(T_a - T_s) \tag{6}$$

And solving for time, we get

$$t_c = \frac{H_L (w_0 - w_c)}{hA(T_a - T_s)}$$

(7)

The time for constant rate period is proportional to the difference between the initial moisture content and critical moisture content, and is inversely proportional to the temperature gradient between the product surface and the heated air.

Falling Rate Period

For the falling rate period, the moisture movement inside the food becomes important. The period begins after the moisture reaches the critical moisture content, and continues until the product reaches the equilibrium moisture content. The moisture diffusion process is dependent upon the shape of the product. (the mathematical solution is similar to the transient heat transfer case that we considered before, here we consider only the first term of the series solution).

For an infinite plate, we get,

$$\frac{w - w_e}{w_c - w_e} = \frac{8}{\pi^2} \exp\left[-\frac{\pi^2 D t}{4 d_c^2} \right] \tag{8}$$

And the drying time will be

$$t_F = \frac{4 d_c^2}{\pi^2 D} \ln\left[\frac{8}{\pi^2} \left(\frac{w_c - w_e}{w - w_e} \right) \right] \tag{9}$$

Similar expressions may be derived for spherical and cylindrical shapes.

Spray Drying

In spray drying, droplets of liquid food formed at the spray nozzle fall inside the chamber, initially they undergo drying at constant rate followed by falling rate. At the bottom of the chamber, dry powder is obtained.

The prediction expression for the total drying time in a spray drier is the combined time for constant and falling rate periods.

$$t = \frac{H_L (w_0 - w_e)}{4 \pi R_d k_a (T_a - T_s)} + \frac{R_p^2}{\pi^2 D} \ln\left[\frac{6}{\pi^2} \left(\frac{w_c - w_e}{w - w_e} \right) \right] \tag{10}$$