TRAY DRYING

INTRODUCTION

Dehydration is a food unit operation that is used to extend the shelf-life of a foodstuff by reducing its water activity (a_w). Drying with hot air using a tray or cabinet dryer is one of the methods of food dehydration. Heat transferred to the surface of a foodstuff exposed to hot air, provides the latent heat of vaporization to evaporate moisture from the food surface. Water vapor diffuses through the film of air that is formed at the food surface and is subsequently removed by the circulating air. A region of low vapor pressure thus forms at the food surface, establishing a vapor pressure gradient between the inner humid layer and the outer layer of dry air. This gradient acts as the driving force of the drying process (Geankoplis, 2003, Toledo, 2007, McCabe et al, 2007)

Drying Curves

A drying process can be represented graphically by recording changes in moisture content of a foodstuff. Drying curves are typically represented as drying rate curves, showing different stages or periods of drying. The drying process begins with an initial short period that allows for the food surface that is heated to reach similar conditions as the hot air (A to B). This initial period of drying is normally considered insignificant in comparison with the two main periods of the overall drying process. The constant rate period (B to C) follows the initial period, where the drying rate is constant. At this stage the food surface is covered completely by a continuous film of free water (water that is not bound to the food surface). As water from the film evaporates, more water from the surface of the food replaces it, thereby keeping the food surface wet.

At a certain point in the drying process, the continuous film of water at the surface cannot be maintained, which results in a significant reduction in water and the surface begins to dry. It is at this point where the critical moisture content is reached and, as the rate of drying decreases, the falling rate period begins. A single falling rate period occurs with non-hydroscopic foods whereas with hydroscopic foods, two (CD and DE) or more periods may occur (Geankoplis, 2003, Fellows 2009). In this period, the evaporation plane moves slowly from the surface to the interior of the food, as the latent heat of vaporization is transferred through the solid to the evaporation area, vaporized water moves through the solid to the circulating air.

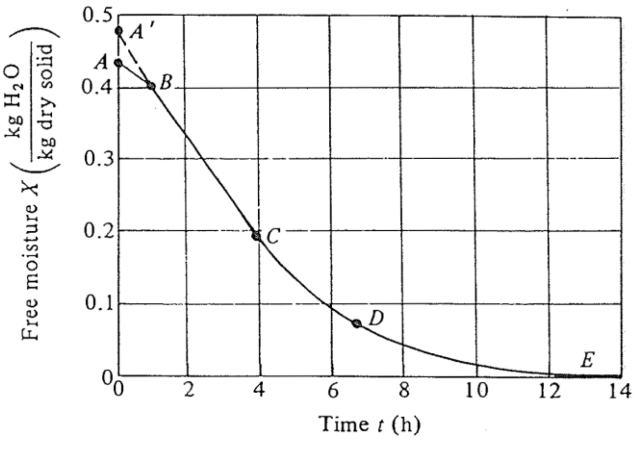

Fig 1

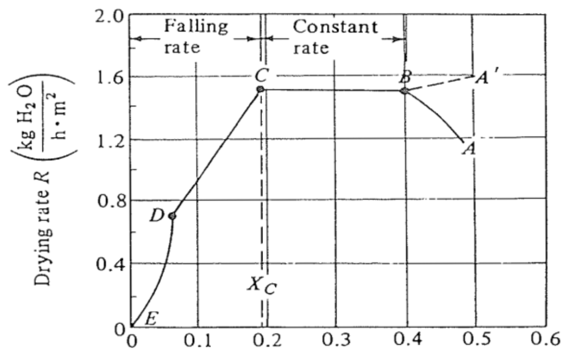

Fig 2

Drying curve (Fig 1) and drying rate curve (Fig 2) for constant drying conditions

Drying Time Calculation

In order to collect appropriate data (the loss of weight from a foodstuff at different drying times) from a drying experiment, in order to construct drying curves, the surface area of the material to be dried, relative air humidity and hot air flow rate should be kept constant during the drying process. The drying curve can be used directly to calculate the drying time, the data can be processed to obtain rate of drying curve. Also, constant and falling rate drying periods can be calculated from the available data.

Determination of the Length of the Constant Rate Period

In this period, the rate of drying, R, can be expressed by:

$$R = -\frac{L_S}{A}\frac{dX}{dt}$$

where X is the free moisture content (kg water/kg of dry solids), t is the drying time (s) drying time, A is the exposed surface area (m^2), and LS is the mass of dry solids (kg) (Geankoplis, 2003). By integration of the above equation between $X=X_1$ for $t_1=0$ and $X=X_2$ for $t_2=t$ the drying time is obtained from:

$$t = \int_{t_1=0}^{t_2=t} dt = \frac{L_S}{A}\int_{X_2}^{X_1}\frac{dX}{R}$$

$$t = \frac{L_S}{AR_C}(X_1 - X_2)$$

where Rc is the constant drying rate (kg water $h^{-1}m^{-2}$)

Determination of the Length of the Falling Rate Period

For the falling rate period, the drying time can be obtained by integration

$$t = \frac{L_S}{A}\int_{X_2}^{X_1}\frac{dX}{R}$$

taking the initial humidity, X_1, below the critical humidity, X_c. This can also be obtained graphically, by representing 1/R as a function of X, and taking the area under the curve for that time period Geankoplis, 2003).

<u>BEFORE COMING TO LAB Read Chapter 9, Pages: 559-587, Geankoplis, C. J. Transport Processes and Separation Process Principles, 4th Ed., Pearson Education Inc.2003</u>

EXPERIMENTAL PROCEDURE

Tray Dryer

The experimental tray dryer is a small scale dryer unit designed. It has a tunnel in which an axial flow fan is mounted at one end. Before the fan there is a set of electrically heated elements which heat the passing through air stream before flowing to the drying chamber. The chamber contains a rack of trays suspended from a scale mounted on top of the drier. The total capacity of the scale is approximately 6 kg with 0.1 g increments. A transparent access door, permits viewing the product while drying. A control panel mounted near the fan allows setting the air speed and air temperature by varying the power of the heater (2 KW).

Additional Apparatus and Materials

The following additional apparatus and materials are required for the experiment:

- Anemometer used to measure the air flow speed (m/s) in the dryer.
- Digital Psychrometer (to measure dry bulb temperature and RH of drying air)
- Infrared dryer (to measure the initial moisture content of fresh mint)
- Food material to be dried: fresh mint or parsley..... **(<u>Approximately 100 grams of one of the above food materials will be supplied by the students</u>)**

Procedure

1. **Measure** tray dimensions and Place one of the tray into middle shelf of the tray dryer
2. Turn on air flow. Adjust flow knob. (Groups may be using different air flow rates. Record exit flow area where you measure velocity to be able to calculate volumetric flow rate)
3. Turn on electrical heater. Set the temperature knob at 12 (max.)
4. Measure the initial moisture content of mint or parsley using the infrared dryer.(use sample size ≥ 5 g) For accurate results you may duplicate measurement.
5. Measure the temperature and RH with the digital psychrometer before the drying chamber before starting the drying process to check if the values are stable. Measure the temperature and RH of the ambient air and record as air to heater.
6. Make several measurements of exit drying air speed(m/s, use mean value in your calculations).
7. Place approximately 30 grams of mint or parsley on the tray and record the initial weight of the material to be dried. (Don't forget setting tare to zero before placing mint)
8. Register the weight of the mints every minute for the first 20 minutes of drying. After this initial period, record these measurements every 5 min. Use this data to calculate and follow moisture content of mint or parsley during drying process.
9. Continue process until a constant weight is reached for the mints or parsley.

DATA ANALYSIS

1. Plot moisture content (kg H_2O / kg dry solid) vs time (min), free moisture content (kg H_2O / kg dry solid) vs time (min), drying rate (kg $H_2O/h.m^2$) vs time, drying rate (kg $H_2O/h.m^2$) vs free moisture content. **(for drying rate calculations to find slopes use linear regression and curve-fitting techniques)**
2. On each graph identify the different periods of drying
3. Find equilibrium and critical moisture content.
4. Calculate (i) the drying time during the constant rate period and (ii) the drying time during the falling rate period using all possible procedures with available data.
5. Calculate Reynolds Number.
6. Search the literature for similar results and compare your results.
7. Calculate thermal efficiency of the heating process, drying process and overall efficiency.

REFERENCES:

- Geankoplis, C. J. Transport Processes and Separation Process Principles, 4th Ed.,Pearson Education Inc.2003
- Toledo, R.T. Fundamentals of Food Process Engineering, 3rd Ed., Springer Science&Media Buiness LLC, 2007
- McCabe W.L, Smith J.C., and Harriot P. Unit Operations of Chemical Engineering, 7 th Ed., 2007
- Fellows, P.J. Food Processing Technology, Principles and Practice, 3 rd Ed., CRC Press, 2009.

DATA SHEET:

The initial moisture content of mint (or):	
Dimensions of tray:	
Exit flow area dimensions (where air velocity was measured):	
Air flow rates(m/s): 1- 2- 3- 4- 5-	

Inlet air to the heater	**Temp:**		**RH:**	

Inlet air to the drying chamber	**Temp:**		**RH:**	

Mint or parsley

Time (min)	Weight (g)	Time (min)	Weight (g)
0		25	
1		30	
2		35	
3		40	
4		45	
5		50	
6		55	
7		60	
8		65	
9		70	
10		75	
11		80	
12		85	
13		90	
14		95	
15		100	
16		105	
17		110	
18		115	
19		120	
20		125	