Salahaddin University - Erbil

College of Agricultural Sciences Engineering

Food Technology Department

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3 Hours

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**Lecture 6 \ Evaporation**

Evaporation is an important unit operation commonly employed to remove water from dilute liquid foods to obtain concentrated liquid products. Removal of water from foods provides microbiological stability and assists in reducing transportation and storage costs.

A typical example of the evaporation process is in the manufacture of tomato paste, usually around 35% to 37% total solids, obtained by evaporating water from tomato juice, which has an initial concentration of 5% to 6% total solids. Evaporation differs from dehydration, since the final product of the evaporation process remains in liquid state. It also differs from distillation, since the vapors produced in the evaporator are not further divided into fractions.



Figure 1: Schematic diagram of a single-effect evaporator

An evaporator can be simplified schematic as shown in Figure 1 (single-effect evaporator). Essentially, an evaporator consists of a heat exchanger enclosed in a large chamber; a noncontact heat exchanger provides the means to transfer heat from low-pressure steam to the product. On the other hand, an evaporator can be a multiple-effect evaporator as shown below in Figure 2, as vapors produced from first and second effects (or evaporation chambers) are used again as the heating medium in second and third effects, respectively.



Figure 2: Schematic diagram of a triple effect evaporator

**Boiling-Point Elevation:**

 Boiling-point elevation of a solution (liquid food) is defined as the increase in boiling point over that of pure water, at a given pressure. A simple method to estimate boiling-point elevation is the use of Dühring’s rule. The Dühring rule states that a linear relationship exists between the boiling-point temperature of the solution and the boiling point temperature of water at the same pressure. The linear relationship does not hold over a wide range of temperatures, but over moderate temperature ranges, it is quite acceptable. Dühring lines for a sodium chloride–water system are shown in Figure 3 illustrates the use of the figure to estimate boiling-point elevation.



Figure 3: Dühring lines illustrating the influence of solute concentrations on boiling point elevation of NaCl

***Dühring's rule***

*A linear relationship exists between the temperatures at which two solutions exert the same vapour pressure.*

**Example:**

Use Dühring’s chart to determine the initial and final boiling point of a liquid food with a composition that exerts vapor pressure similar to that of sodium chloride solution. The pressure in the evaporator is 20 kPa. The product is being concentrated from 5% to 25% total solids concentration. Boiling point of water at 20 kPa is 333 Kelvin.

**Given:**

Initial concentration = 5% total solids

Final concentration = 25% total solids

Pressure = 20 kPa

Boiling point of water at 20 kPa is 60 ℃.

**Approach:**

To use Dühring’s chart, given in Figure 3, we need the boiling point of water. This value is obtained from the steam tables. The boiling point of the liquid food can then be read directly from Figure 3.

**Solution:**

From Figure 3,

Boiling point at initial concentration of 5% total solids is 333 K = 60°C

Boiling point at final concentration of 25% total solids is 337 K = 64°C

**Types of Evaporators:**

1. Batch-type pan evaporators.
2. Natural circulation evaporator.
3. Rising-film evaporator.
4. Falling-film evaporator.
5. Rising/Falling film Evaporator.
6. Forced-circulation evaporator.
7. Agitated thin film evaporator.

**Vapor Recompression Systems:**

In an evaporator, dilute liquid feed is pumped into the heating chamber, where it is heated indirectly with steam. Steam is introduced into the heat exchanger, where it condenses to give up its heat of vaporization to the feed, and exits the system as condensate. Vapor recompression assist in reduction of energy requirements. These systems are thermal recompression and mechanical vapor recompression.

**Thermal Recompression:**

Thermal recompression involves the use of a steam jet booster to recompress part of the exit vapors. Through recompression, the pressure and temperature of exit vapors are increased. Application of this system requires that steam be available at high pressure, and low pressure steam is needed for the evaporation process. This system is used usually in single-effect evaporators.

**Mechanical Vapor Recompression:**

 Mechanical vapor recompression involves compression of all vapors leaving the evaporator. Vapor compression is accomplished mechanically, using a compressor driven by an electric motor, a steam turbine, or a gas engine.

Mechanical vapor recompression systems are very effective in reducing energy demands. These systems can be very noisy to operate due to the use of large compressors.

**For more reading:**

Singh, R. and Heldman, D., 2009. *Introduction to food engineering*. 4th ed. Ohio: Elsevier.