Chapter 3

Theory of Grain Drying

Generally, the term "drying" refers to the removal of relatively small amount of moisture from a solid or nearly solid material by evaporation. Therefore, drying involves both heat and mass transfer operations simultaneously. In convective drying, the heat required for evaporating moisture from the drying product is supplied by the external drying medium, usually air. Owing to the basic differences in drying characteristics of grains in thin layer and deep bed, the whole grain drying process is divided into thin layer drying and deep bed drying.

Thin Layer Drying

Thin layer drying refers to the grain drying process in which all grains are fully exposed to the drying air under constant drying conditions, i.e., at constant air temperature and humidity. Generally, up to 20 cm thickness of grain bed (with a recommended air–grain ratio) is taken as thin layer.

All commercial flow dryers are designed on thin layer drying principles.

The process of drying should be approached from two points of view: the equilibrium relationship and the drying rate relationship.

For convenience, a few terms used in describing the drying process are defined and discussed.

Moisture Content

Usually, the moisture content of a substance is expressed in percentage by weight on wet basis. But the moisture content on dry basis (d.b.) is more simple to use in calculation as the quantity of moisture present at any time is directly proportional to the moisture content on d.b.

The moisture content, m, percent, wet basis is

$$m = \frac{W_m}{W_m + W_d} \times 100 \tag{3.1}$$

where

W_m is the weight of moisture
W_d is the weight of bone dry material

The moisture content, M, d.b., percent is

$$M = \frac{W_m}{W_d} \times 100 = \frac{m}{100 - m} \times 100 \tag{3.2}$$

The moisture content, X, d.b, is sometimes expressed in decimal also as follows:

$$X = \frac{M}{100} \tag{3.3}$$

Two additional useful equations for moisture content are given later for the following calculation:

$$\frac{W'_m}{W_1} = \frac{m_1 - m_2}{100 - m_2} = \frac{M_1 - M_2}{100 + M_1} \tag{3.3a}$$

$$\frac{W'_m}{W_2} = \frac{m_1 - m_2}{100 - m_1} = \frac{M_1 - M_2}{100 + M_2} \tag{3.3b}$$

where

W_1 is the initial weight of wet material = (W_m + W_d), kg
W_2 is the final weight of dried product, kg
W'_m is the weight of moisture evaporated, kg
m_1 and m_2 are initial and final moisture contents, respectively, percent, wet basis
M_1 and M_2 are initial and final moisture contents, respectively, d.b., percent

Moisture Measurement

Moisture content can be determined by direct and indirect methods. Direct methods include air-oven drying method (130°C ± 2°C) and distillation method. Direct methods are simple and accurate but time-consuming, whereas indirect methods are convenient and quick but less accurate.

Direct Methods

The air-oven drying method can be accomplished in a single stage or double stage in accordance with the grain samples containing either less or more than 13% moisture content (Hall, 1957).

Single Stage Method

Single stage method consists of the following steps:

1. Grind 2–3 g sample.
2. Keep the sample in the oven for about 1 h at 130°C ± 2°C.
3. Place the sample in a desiccator and then weigh it after cooling.

Double Stage Method

1. In this method, keep 25–30 g whole grain sample in the air oven at 130°C ± 2°C for 14–16 h so that its moisture content is reduced to about 13%.
2. Then follow the same procedure as in single stage method.

Other Methods

Place the whole grain sample in the air oven at 100°C ± 2°C for 24–36 h depending on the type of grain and then weigh it.

The vacuum oven drying method is also used for determining the moisture content.

However, moisture determination should be made according to the standard procedure for each grain which is laid down by the Government or by the Association of Agricultural Chemists.

Brown–Duvel Distillation Method

The distillation method directly measures the volume of moisture, in cc condensed in a measuring cylinder by heating a mixture of 100 g grain and 150 cc oil in a flask at 200°C for 30–40 min.

Moisture content can be measured by the toluene distillation method also.

Indirect Methods

Indirect methods are based on the measurement of a property of the grain that depends upon moisture content.

Two indirect methods are described as follows.

Electrical Resistance Method

Resistance type moisture meter measures the electrical resistance of a measured amount of grain sample at a given compaction (bulk density) and temperature. The electrical resistance varies with moisture, temperature, and degree or compaction.

The universal moisture meter (the United States), Tag–Happenstall moisture meter (the United States), and Kett moisture meter (Japan) are some of the resistance-type moisture meters. They take only 30 s for the moisture measurement.

Dielectric Method

The dielectric properties of grain depend on its moisture content. In this type of moisture meter, 200 g grain sample is placed between the condenser plates and the capacitance is measured. The measured capacitance varies with moisture, temperature, and degree of compaction.

The Motomco moisture meter (the United States) and Burrows moisture recorder (the United States) are some of the capacitance-type of moisture meters. They take about 1 min to measure the moisture. These are also known as safe crop moisture testers as they do not damage the grain sample.

Equilibrium Moisture Content

When a solid is exposed to a continual supply of air at constant temperature and humidity, having a fixed partial pressure of the vapor, p the solid will either lose moisture by evaporation or gain moisture from the air until the vapor pressure of the moisture of the solid equals p. The solid and the gas are then in equilibrium and the moisture content of the solid in equilibrium with the surrounding conditions is known as equilibrium moisture content (EMC) (Figure 3.1). The EMC is useful to determine whether a product will gain or lose moisture under a given set of temperature and relative humidity conditions. Thus, EMC is directly related to drying and storage. Different materials have different EMCs. The EMC is dependent upon the temperature and relative humidity of the environment and on the variety and maturity of the grain. The EMC of different grains at different temperatures and humidities are given in Table A.1. A plot of the equilibrium relative humidity and moisture content of a particular material at a particular temperature (usually 25°C) is known as equilibrium moisture curve or isotherm. Grain isotherms are generally S-shaped and attributed to multimolecular adsorption.