SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)
Coimbatore – 641035.

Unit 1 – Topic 4

Moisture content - measurement - direct and indirect methods - moisture meters

Food and Moisture

Food is any substance consumed to provide nutritional support for the body. It is usually of plant or animal origin, and contains essential nutrients, such as carbohydrates, fats, proteins, vitamins, or minerals. All foods content solids, water and other chemicals. The moisture contained in a material comprises all those substances which vaporize on heating and lead to weight loss of the sample. The weight is determined by a balance and interpreted as the moisture content. According to this definition, moisture content includes not only water but also other mass losses such as evaporating organic solvents, alcohols, greases, oils, aromatic components, as well as decomposition and combustion products. The moisture content also called as moisture assays is one of the most important analyses performed on most of the food products.

Types of bonding of moisture in the product

The moisture in food can be present in different forms which are decided by type of bonding with solids (Fig 1). It is available in following forms:

Free water: water on the surface of the test substance and it retains its physical form

Absorbed water: water in large pores, cavities or capillaries of the test substance

Water of hydration: Occluded in lattice ions or water of crystallization coordinately bonded to ions.

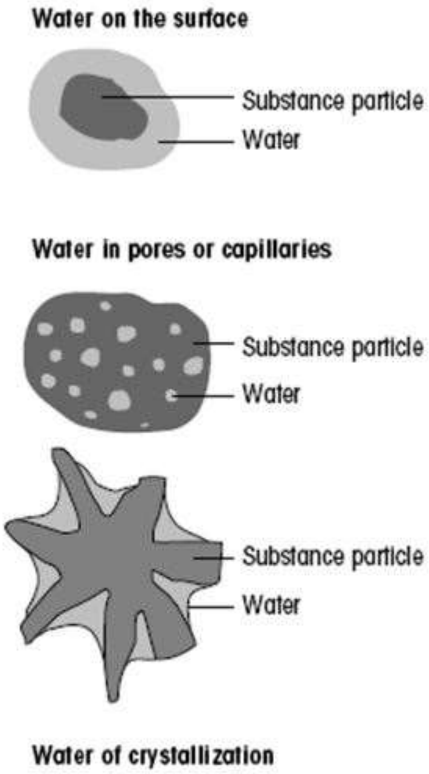

Fig 1.1 Types of bonding of moisture in food products

1.3 Esimation of Moisture Content

Moisture content is the quantity of water contained in a food material. Moisture content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis. Moisture content is expressed as a percentage of moisture based on total weight (wet basis) or dry matter (dry basis). Wet basis moisture content is generally used. Dry basis is used primarily in research. The moisture content is expressed by following formulae.

$$M_w(\text{wet basis}) = \frac{w - d}{w} \times 100$$

$$M_d(\text{dry basis}) = \frac{w - d}{d} \times 100$$

where, M is moisture content on a percent basis, w is total weight (also called as wet weight) and d is dry weight.

Based on the different forms of moisture present in the food the method used for measurement of moisture may estimate more or less moisture content. Therefore, for different food products *Official Methods* of moisture measurement have been given by agencies like AOAC (Association of Official Analytical Chemists), AACC (American Association of Cereal Chemists) and BIS (Bureau of Indian Standards).

1.4 Importance of Moisture Content in Foods

Proper moisture content is essential for maintaining fresh, healthy foods. If a food is too moist or too dry, it may not be suitable to eat and will not taste as good as it would if it had the correct moisture content. Most of the food products contain moisture. The moisture content per cent is seldom of interest. Rather, it shows whether a product intended for trade and production has standard characteristics such as:

1. Storability

2. Agglomeration in the case of powders

3. Microbiological stability

4. Flow properties, viscosity

5. Dry substance content

6. Concentration or purity

7. Commercial grade (compliance with quality agreements)

8. Nutritional value of the product

9. Legal conformity (statutory regulations governing food)

In addition to above characteristics, the determination of moisture content plays important role commercially with respect to following aspects:

1. Freshness

Fresh, ripe fruits and vegetables are moist to the touch. As they age and begin to rot, some dry out and some pick up excess moisture and begin to mold.

2. Labeling

Food industries require a minimum or maximum percentage of moisture on certain foods in order for them to be packaged and labeled. If they don't fit to these standards, the foods cannot be sold.

3. Cost

In processed foods, the percentage of water in a product can determine its final price. Generally, a product with more water will cost less.

4. Processing

Biologists and manufacturers need to know the moisture content of food to ensure that it's processed and packaged in a safe, stable way.

5. Quality

Moisture content determines the way most foods taste, feel and look. It is one of the important ways to measure food quality.

6. Shelf life

Shelf life of product depends on its moisture content at the time of packaging and rate of moisture gain during storage which is also called as sorption isotherm study.

Determination Of Moisture Content

The moisture content is determined by several direct and indirect methods. These can be classified in different sections as shown in Figure 1.

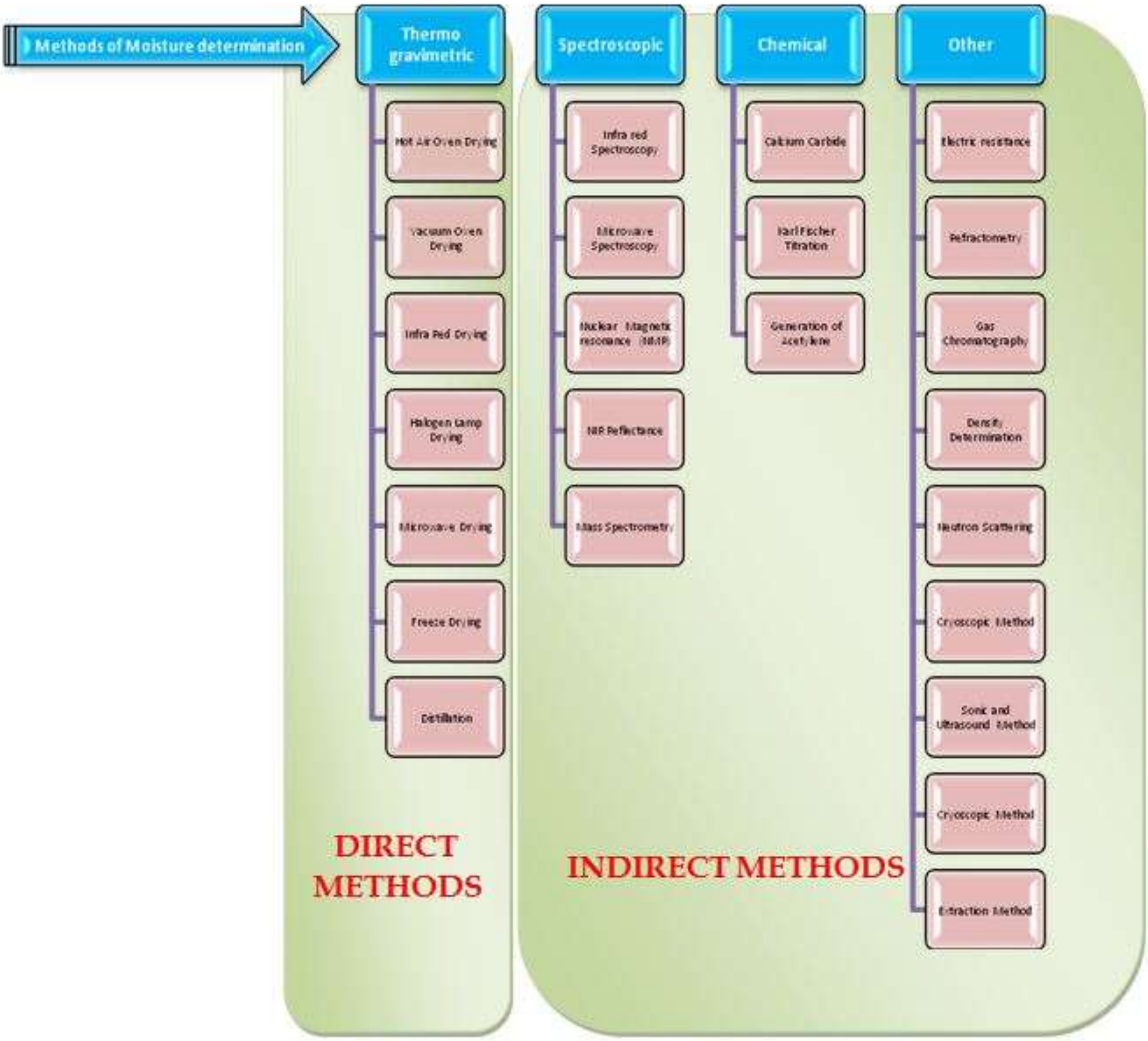

Figure 2.1: Classification of methods of moisture determination

2.1 Direct Methods

The direct methods include mainly thermo gravimetric methods. The moisture content can be determined by an oven method directly. The food is weighed and dried, then weighed again according to standardized procedures. In the Thermogravimetric method, moisture is always separated. Thus, there is no distinction made between water and other readily volatile product components. A representative sample must be obtained to provide a useful moisture content evaluation. Also, the moisture content of the product must be maintained from the time the sample is obtained until the determination is made by storing in a sealed container. Thermogravimetric techniques can be used to continuously measure the mass of a sample as it is heated at a controlled rate. The temperature at which water evaporates depends on its molecular environment: free water normally evaporates at a lower temperature than bound water. Thus by measuring the change in the mass of a sample as it loses water during heating it is often possible to obtain an indication of the amounts of water present in different molecular environments. The figure 2 shows the process of measuring moisture content thermo gravimetrically. For many food samples this method is mandatory particularly for grains. For grains the moisture content is measured by heating the grain in hot air oven at 100-110 °C for 24 hours or until constant weight comes. For fruits and vegetables where heat sensitivity is problem, vacuum is applied in the oven to decrease the boiling point of moisture. The product temperature generally varies in vacuum oven between 60-70°C and vacuum is maintained at <450 mm Hg. The advantages and disadvantages of direct methods are given in Table 1 which can be used for selection of particular method for moisture content determination.

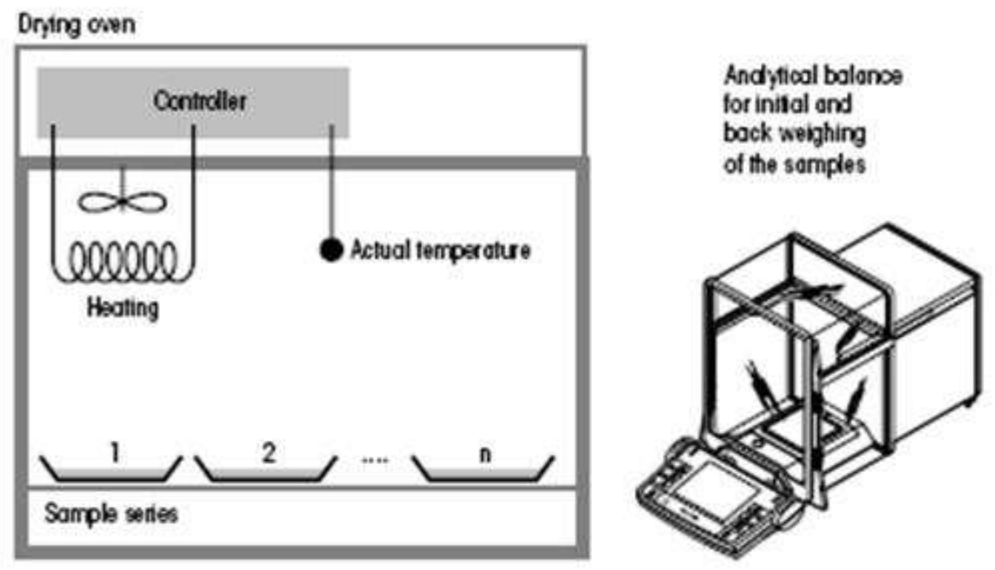

fig. 2.1 determination of moisture content by oven drying

Table 1: Advantages and Disadvantages of direct Methods for Moisture

Method	Advantages	Disadvantages
Oven drying	Standard conventional method	Variations of temperature due to particle size, sample weight, position in the oven, etc.
	Convenient	Difficult to remove all water
	Relative speed and precision	Loss of volatile substances during drying
	Accommodates large number of samples	Decomposition of sample (i.e., sugar)
	Attain the desired temperature more rapidly	
Vacuum-oven drying	Lower heating temperatures possible	Possible volatile loss
	Prevents sample decomposition	Lower number of samples than drying oven
	Uniform heating and constant evaporation	Drying efficiency reduced for high-moisture foods
Freeze-drying	Excellent for sensitive, high-value liquid foods	Expensive
	Preserves texture and appearance	Long drying time
	No foaming	Sample must be initially frozen
	No case-hardening	Most applicable to high moisture foods
	No oxidation	
	No bacterial changes during drying	
Distillation methods	Determines water directly rather than weight loss	Low precision of measuring device
	Apparatus is simple to handle	Organic solvents such as toluene pose a fire hazard
	Accuracy may be greater than oven-drying method	Organic solvents may be toxic
	Takes relatively short time (30 min to 1 h) to determine	Can have higher results due to distillation of water-soluble components (e.g., glycerol and alcohol)
	Prevents oxidation of sample	Water droplets may adhere to internal surface of the apparatus, causing erroneous results
	Not affected by environmental humidity	Emulsions may form
	Suitable for samples containing volatile substances	
Karl Fischer method	A standard method for moisture analysis	Chemicals of the highest purity must be used for preparing the reagent
	The accuracy and precision are higher than with other methods	Titration endpoint may be difficult to determine visually

Method	Advantages	Disadvantages
	Useful for determining water in fats and oils by preventing oxidation	The reagent is unstable and needs standardization before use
	Once the apparatus is set up, determination takes a few minutes	Titration apparatus must be protected from atmospheric moisture due to extreme sensitivity of reagent to moisture
	Automated equipment available	Ascorbic acid and other carbonyls can react with reagents, causing over-estimation of the moisture content
Chemical desiccation	Can serve as a reference standard for other methods	Requires a long time to achieve constant dry weight
	Can be done at room temperature	Moisture equilibrium depends on strength of desiccant
	Good for measuring moisture in substances containing volatile compounds	
Thermogravimetric analysis	More automated method than standard oven drying	Excellent for research, but not practical
	Weighing error is minimal because sample is not removed from oven	Small sample may not be representative
	Sample size is small	Sample may decompose or oxidize
GC	Analysis is rapid (takes 5–10 min per sample)	Unit cost per sample may be higher than drying oven
	Results similar to conventional methods	Sample extraction required
		Requires expensive equipment

Source: Park, Y.W. in *Handbook of Food Analysis*, Marcel Dekker, New York, 1996, 59–92; Park, Y.W. and L.N. Bell in *Handbook of Food Analysis*, Marcel Dekker, New York, 2002, 55–82.

2.2 Indirect Methods

There are several methods developed to determine the moisture content rapidly. These include use of modern heating, measurement methods like infrared, microwaves, ultra sound, and spectroscopy. These methods are developed due to requirements of rapid, nondestructive and precise moisture content determination. The indirect methods are generally faster than the direct methods for moisture determination. When done properly, the indirect methods can be as accurate and precise. However, the accuracy and precision of the indirect methods depend on careful preparation and analysis of known standards to establish reliable calibration curves. Although most indirect methods require a large capital investment in equipment, the potential application for rapid on-line quality control might make the investment worthwhile. Nevertheless, preparation of the standards and accurate calibration curves must be verified by a specific direct method to establish a reliable indirect method of instrumentation that can achieve accurate and precise predicted values. One of the most important indirect methods in foods is use of moisture meters for grains. Most moisture meters measure the electrical properties of grain, which change with the moisture content. This is considered an indirect method and must be calibrated by a direct method. It is important to follow moisture meter directions carefully to achieve an accurate moisture test. A moisture meter should be periodically checked to see if it is accurate. One method of checking the meter is to compare it to at least two other meters. There are several factors that control use of each method. The advantages and disadvantages of indirect methods are given in Table 2.

Table 2: Advantages and Disadvantages of indirect Methods for Moisture Determination

Method	*Advantages*	*Disadvantages*
Refractometry	Determination takes only 5–10 min (rapid)	Temperature sensitive
	Does not require complex or expensive instrumentation	Requires uniformity of fluid samples
	Simple method	Solid samples (e.g., meat) require homogenization in an anhydrous solvent
	Reasonable accuracy	
	Excellent method for high-sugar products	
IR Absorption	Can perform multicomponent analysis	Accuracy depends on calibration against reference standard
	Most versatile and selective	Temperature-dependent
	Nondestructive analysis	Dependent on homogenization efficiency of sample
		Absorption band of water is not specific
NIR reflectance spectroscopy	Rapid	Reflectance data are affected by sample particle size, shape, packing density, and homogeneity
	Precise	Interference between chemical groups (e.g., hydroxyl and amine)
	Nondestructive	Temperature-dependent
	No extraction required	Accuracy depends on calibration of standard samples
	Minimum sample preparation	Equipment is expensive
Microwave absorption	Nondestructive	Possible leakage of microwave energy during measurement
	No extraction required	Has relatively low sensitivity and limited range for moisture determinations
	More accurate than low-frequency resistance or capacitance meters	Depends on the fluctuation of the material density in the volume measured
		Results affected by factors such as particle size, temperature, soluble salt contents, polarization, and frequency of sample
Dielectric Capacitance	Has high sensitivity due to large dielectric constant of water	Affected by texture of sample, packing, electrolytes, temperature, and moisture distribution
	Convenient to industrial operations with the continuous measurement system	Potential calibration difficulty beyond pH 2.7–6.7
	System can be modified to have universal applicability	Difficult to measure bound water at high frequencies
Conductivity	Measurement is instantaneous	Measures only free water
	Nondestructive	Conversion charts are needed to obtain total moisture values

2.3 Problem:

1. Suppose, for example, that you weigh 10 g of grains (W_w) into a 4 g container and that after drying the container plus grains weighs 6.3 g. Subtracting out the 4-g. container weight leaves 2.3 g as the dry weight (W_d) of your sample. Percent moisture would be:

$M_n = ((W_w - W_d)/W_w) \times 100$
$= ((10 - 2.3) / 10) \times 100$
$= 77\%$