Determination of Moisture Content

1. Introduction:

Drying, storage, marketing, and roasting are four important aspects of coffee handling in which moisture plays an important role:

- *Drying*: moisture measurement at the end of drying is essential to follow up drying course and to decide whether it is achieved or not. On one hand, too long a drying course may have bad consequences for quality and food safety because of unexpected fermentations and mould growth. On the other hand, the next step in the process is storage. Also, drying to a too low moisture content can result in income losses - for example, a truck which weighs 1000 kg with beans at 12 % moisture, will weight only 967 kg at 9 % moisture;

- *Storage*: storing coffee with too high a moisture content may involve high risks of mould growth and OTA production;

- *Marketing*: a cargo of 25,000 tons of coffee at 12 % moisture represents 3000 tonnes of water. At 14.5 %, the cargo contains 3,625 tons of water. At just 0.20 $ per kg, this difference is worth $125,000;

- *Roasting*: temperature and length of roasting are adjusted to a usual moisture of 12 % to 13 %. Above these values, roasting requires more energy and might be incomplete. Below these values, beans might end up being over-roasted.

2. Methods of Measuring Moisture Content:

The methods of determining moisture content in coffee can be divided into three broad categories:

- *Direct measurement*: water content is determined by removing moisture and then by measuring weight loss;

- *Indirect measurement*: an intermediate variable is measured and then converted into moisture content. Building up calibration charts before applying indirect measurements is a prerequisite;

- *Empirical measurement*: refers to methods such as biting, shaking, crunching, commonly used by both producers and small traders. These empirical measurements are both indirect and subjective. Surveys carried out during the 'Enhancement of Coffee Quality through the Prevention of Mould Formation' project have shown that these subjective methods of moisture determination to be insensitive over the range 12–20% moisture content, and therefore ***unsuitable*** for determining the end of drying (i.e. when coffee has a maximum of 12% moisture), or for verifying that coffee in the marketing chain is at a safe moisture content.

2.1. Direct measurements

Different methods are used to remove all the water but chemically bound water: heating in an oven, use of microwaves or infrared radiation. For coffee beans, a reference method has been established (ISO 1446: Green coffee – Determination of water content – Basic reference method).

Moisture content is given with the relation $\%mc_{wb} = \frac{W_w - W_d}{W_w} \times 100$, where mc is expressed on wet basis (W_w is wet weight and W_d is dry weight).

Moisture can be expressed on dry basis $\%mc_{wb} = \frac{W_w - W_d}{W_d} \times 100$, this value sometimes being used for particular studies.

The conversion $mc_{wb} \Leftrightarrow mc_{db}$ is given by following formulae:

$$mc_{wb} = \frac{mc_{db}}{1 + mc_{db}} \quad \text{and} \quad mc_{db} = \frac{mc_{wb}}{1 - mc_{wb}}$$

Table 1: Moisture content conversion (%) wet basis to dry basis (decimal)

w.b. (%)	d.b.	w.b. (%)	d.b.	w.b. (%)	d.b.
8.0	0,087	15.0	0,176	22.0	0,282
9.0	0,099	16.0	0,190	23.0	0,299
10.0	0,111	17.0	0,200	24.0	0,316
11.0	0,123	18.0	0,220	25.0	0,333
12.0	0,136	19.0	0,234	26.0	0,351
13.0	0,150	20.0	0,250	27.0	0,370
14.0	0,163	21.0	0,265	28.0	0,389

Direct methods are considered to provide true measurements of moisture content, and are used to calibrate more practical and faster indirect methods.

Direct methods are mainly devoted to research purposes because it requires special equipment (e.g. an oven and analytical balance), and measurements can only be implemented in laboratories. They also take time.

2.1.1. Modified distillation method

One relatively rapid direct method of moisture determination developed in Brazil (EDABO method) is being applied by some agricultural enterprises in their field operations. The EDABO method (direct evaporation of water in an oil bath), is a variation of the official Brawn-Duvel distillation method. This method, which is illustrated and described below, takes about 20 minutes.

Steps in the determination of the moisture content of a lot of grain using the EDABO method are as follows:

- Prepare a representative sample of the product;

- Weigh 100 g of the product (using a scale of capacity 500 g, with accuracy ± 0.5 g) and place the sample (100 g) in a recipient of approximately 10 cm diameter and 20 cm height, resistant to high temperatures, with a perforated cover fitted with a graduated thermometer reading up to 250°C;

- Add sufficient vegetable oil (soybeans or other) to cover the 100 g of the product;

- Weigh the recipient + product + oil + thermometer and register the initial weight (Wi);

- Heat up the system (recipient + product + oil + thermometer), until the required temperature shown in Table 2 is reached (approximately 15 minutes). Turn off the heat and wait until the bubbles stop. Weigh the system again (recipient + product + oil + thermometer) and call it (Wf);

- Subtract (Wf) from (Wi) and to register the moisture content directly in % w.b.

Example: If Wi = 458.9 g; Wf = 445.4 g; the difference Wi - Wf; = 13.5 g, or 13.5% w.b.

Table 2 - Temperature for moisture content using the EDABO method

PRODUCT	TEMPERATURE (°C)	PRODUCT	TEMPERATURE (°C)
Rice	200	Corn	195
Hulled rice	195	Soybean	135
Natural coffee	200	Sorghum	195
Green coffee	**190**	Wheat	190
Beans	175		

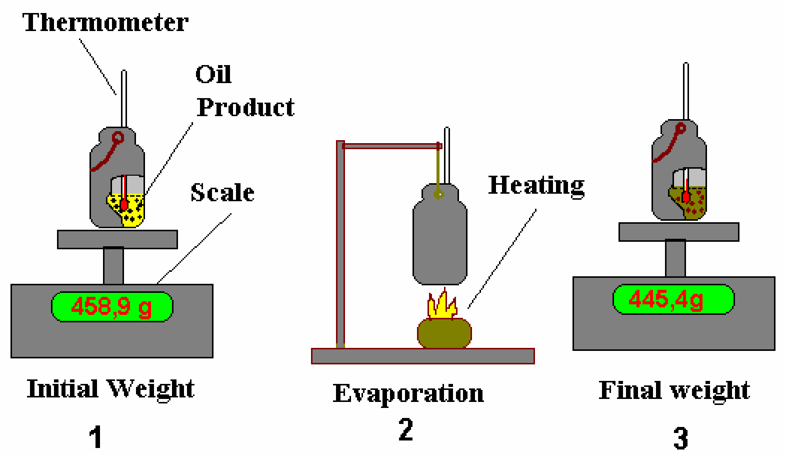

Fig. 1: Schematic representation of the EDABO method.

Fig. 2: Basic element of the EDABO method

2.2. Indirect measurements

2.2.1. Moisture meters

All commonly used methods are based on electrical property of beans. An electrical current unit, resistance or capacitance, is measured and then converted into moisture content.

Resistance: the meter measures the electrical resistance of beans when a current is applied between two electrodes. Beans are placed in a constant and known volume.

Capacitance: the meter measures an electrical current between two plates of a condenser which constitute the walls of a recipient. A precise weight of sample is required.

In both techniques, temperature corrections are required for accurate measurements. Most of moisture meters are equipped with temperature correction software.

Limits of the method: calibration charts must be established for each grain type. This means that a meter must be calibrated separately for robusta beans and arabica beans, but also for cherries and parchment to obtain accurate measurements. Accurate measurements are obtained within a range given by the manufacturer. Over this range, readings have no meaning.

2.2.2. Hygrometers

These devices measure the relative humidity in the air space between beans. Values given by these meters refer to water activity of beans and are useful for microbiological purposes. The accuracy of measurements depends on the uniformity of the distribution of moisture in the sample and equilibration must be achieved to have reliable measurements. For high moistures, equilibration time may take few hours.

Limits of the method: measures do not give moisture content of the product directly. Calibration charts must be established based on desorption and sorption studies. Relations are rather complex and use either mc on a wet or dry basis.

Note that often desorption curves do not overlap with sorption curves, so far this method implies different calibration charts whether coffee is in a drying or a rewetting process.

2.2.3. Weight of a constant volume

This principle is based on variations of apparent density of coffee throughout drying courses. The weight is then converted into moisture content. Theoretically, the weight decreases uniformly day after day as water evaporates from the coffee, and when drying is achieved the weight remains more or less constant.

Limits of the method: apparent density is commonly used with cereals but the goal is not to determine mc but to estimate how grains are filled. When apparent density is determined, moisture content is controlled before and must be around 13 %-14%.

In the case of coffee, whether beans, cherries or parchment, there are variations of density linked with size of beans and its distribution, nutrition of trees, weather conditions, etc. So, there is no constant density for each type of coffee. Due to this, to recommend an average weight of beans, dry cherries or dry parchment at a known moisture and for a known volume, does not ensure that this weight is an accurate standard

2.2.4. *Calibration*

Indirect methods always need to establish calibration charts by using standards of known moisture content. Standards are prepared by using a direct method to determine moisture.

Preparing standards: the size (weight or volume, depending of the type of the equipment) of the standard must meet the recommendation of the manufacturer. Because the distribution of moisture in a sample is not uniform, the standard must be divided in several sub-samples which the weight of each of them fits with official recommendations. Moisture content is determined for each sub-sample. The mean of all values represents the standard. Then all sub-samples are bulked and kept in a sealed recipient to avoid uptake of water. Different standards, covering the range of the equipment must be prepared. Usually, in the case of hygrometers, manufacturers provide standards.

Verification of functioning of the equipment: readings and exact values are plotted on a same graph and data are analysed to verify if the response of the equipment is always the same. Practically speaking, the two curves must be more or less parallel. If not, the equipment must be returned to the manufacturer and should not be used.

Verification of calibration: the goal of calibration is to ensure that the two curves from the previous step overlap as well as possible. Most modern equipment is equipped with switches which allow adjustments of readings. After filling up the recipient of the meter, the exact value of the standard can be entered. Some equipment allows only one value (single point calibration) whereas others allow several. When this is done, the equipment gives the exact value of moisture of any sample under the condition that respects the range of use of the meter.

In case, it is not possible to auto-calibrate the meter, readings and exact values of standards are plotted together in order to establish the relation:

$$mc = A \times Readings + B$$

A calibration chart can then be computed from this relation.

Moisture contents of unknown samples are determined by indirect measurements and then by oven drying as recommended to prepare standards. Readings or corresponding values from the calibration chart are compared with mc by oven drying. When values are equal, the calibration is considered to be achieved otherwise, it must be done again and the stability of readings for a same standard must be assessed. This can be done by measuring mc of standards with the meter several times.

Limits of calibration: for commercial purposes, calibration must be done by officially recognised institutions, but for field activities, it can be done in any properly equipped laboratory.

In general, moisture meters are calibrated for beans but they also can be used for dry cherries and dry parchment though there is no ISO method to determine moisture content of these two products. In this case, the best is to establish a calibration chart using the same method as for beans to determine mc by oven drying.