The Challenges of Measuring Moisture Content

By Brady Carter

Moisture content is a measure of the quantity of water in a product and the terms moisture content and water content are often used interchangeably. Moisture content provides valuable information about yield and quantity, making it important from a financial standpoint. In addition, moisture content provides information about texture since increasing levels of moisture provide mobility and lower the glass transition temperature. Moisture content and water activity together provide a complete moisture analysis. Water activity, which provides information about product safety and quality, is often thought to be a more complicated measurement than moisture content. However, this application note will show why moisture content may not be as simple as it seems.

Reporting Method

The concept of moisture content seems basic enough. All that is needed is a determination of the amount of water in a product and compare that to the weight of everything else in the product. While it is simple in theory, further investigation of moisture content demonstrates that for such a simple concept, it is an extremely complex process to actually obtain an accurate moisture content measurement. For example, moisture content can be reported on either a wet or a dry basis. For the wet basis, the amount of water is divided by the total weight of the sample (solids plus moisture) while for the dry basis, the amount of water is divided by the dry weight (solids only). Unfortunately, in many cases when moisture content is reported, there is no differentiation between the two reporting methods. It is just simply reported as a percentage. Also, moisture content reported on a dry basis can actually result in a percentage value greater than 100%, which can be confusing. Thankfully, it is an easy conversion to go between wet basis and dry basis, however, confusion and potential problems can occur when comparisons are being made between moisture contents that are being reported on a different basis.

Measurement Method

The complications do not end with reporting method. When it comes to determining the amount of water in a product, there are many choices available. The AOAC lists 35

different methods for measuring moisture content. These are classified as either direct or indirect measurement methods. Direct methods require removing the water from the product using drying, distillation, extraction, or other method and then measuring the amount of water by weighing or titrating. Direct methods provide the most reliable results, but are usually labor intensive and time consuming. Examples of direct measurement methods include: air-oven drying, vacuum oven-drying, freeze-drying, distillation, Karl Fischer, thermogravimetric, chemical desiccation, and gas chromatography.

Indirect methods do not remove the water from the sample but instead measure some property of the food that changes as moisture content changes. These are secondary methods and require calibration to a primary or direct method. Their accuracy is limited by the accuracy of the primary method. Indirect methods are usually fast and require little sample preparation, but are less reliable than direct measurement methods. Examples of indirect measurement methods include: refractometry, IR absorption, NIR absorption, microwave adsorption, dielectric capacitance, conductivity, and ultrasonic absorption.

Further complicating the process of measuring moisture content is that one measurement method will not necessarily provide the same results as another, making it difficult to make any kind of comparisons, especially since the measurement method is normally not reported with the moisture content. Even direct measurement methods do not provide consistent results. Any method that requires heating the sample (i.e. loss on drying) can lead to the loss of organic volatiles or decomposition of the sample (especially for samples containing high levels of sugar). For example, if organic volatiles are present in a sample or if the sample decomposes while being dried, a Karl Fischer analysis, which is not susceptible to volatiles loss or decomposition, will give different results than a loss on drying analysis.

Reliability of Method

Consistency in method choice for moisture content analysis still will not eliminate all problems. Consider for instance, loss on drying. This method seems simple enough. A sample is weighed and the weight is

recorded. The sample is then transferred to an oven, allowed to dry, and the dry weight is measured. The amount of water is determined by subtracting the dry weight from the initial weight and the moisture content is then calculated as the amount of water divided by the dry weight or total weight depending on the reporting method.

While the method is simple, the opportunities for variation are many. First, the term 'dry' has no real scientific meaning and has never been well defined. Instead, an arbitrary dryness that is reproducible has to be established for each sample. This dryness state is often defined as the point at which weight loss ends. However, thermogravimetric graphs for different products indicate that the temperature at which weight loss levels off is different for each product, as is the time needed at that temperature to achieve 'dryness'. Also, the temperature needed to achieve dryness for one product type may be the decomposition temperature for another product. This means that each sample has an ideal oven temperature and drying time. While the ideal time/temperature combination is available for some products from the literature, it is not available for all product types, making it difficult to know which combination to use if the information is not available. If the same time/temperature combination is not used, the resulting moisture contents should not be compared.

Of further complication is that many ovens set at one temperature can vary over time from that temperature by as much as 15 °C and two ovens set to the same temperature can vary by as much as 40 °C.

Additional sources of variation for just the loss on drying method include: oven vapor pressure, sample preparation, particle size, sample weighing, and post-drying treatment. It is interesting that despite all of the potential pitfalls associated with loss on drying, when a moisture content is reported in literature, it is immediately accepted as correct. In addition, when comparisons are made between moisture content methods and one of those methods is loss on drying, it is always assumed that the loss on drying measurement is correct.

What is "Dry"?

Defining "dry" would be helpful in eliminating some of the inconsistency associated with moisture measurement. The

best way to define dry would be to identify an oven dry water activity. Then, the dry weight would be the weight of the sample when it has achieved this oven dry water activity. Under common ambient conditions of 25 °C and 30% RH, an oven set to 95 °C would create an oven dry water activity of 0.01 a_w inside the oven, assuming that the vapor pressure in the oven is the same as the air. An oven that maintained conditions such that its oven dry water activity was always 0.01 regardless of ambient conditions would create a scientifically "dry" condition. Any product could be declared dry when its weight stopped changing in this type of oven. Its water activity would be 0.01 a_w and its weight would be the dry weight. The vapor pressure and temperature of the oven could be adjusted to prevent release of volatiles as well, as long as the water activity in the oven was maintained at 0.01 a_w. Using this method would eliminate the inconsistency that results from multiple measurement methods and not having a definition of "dry."

Summary

The potential problems associated with using the amount of water in a product to tell a story it doesn't really tell, like whether the product is microbially safe, are well documented in several of Decagon's application notes. This application note serves to further demonstrate that obtaining correct and consistent moisture content values can be difficult and a moisture content cannot be taken at face value without additional information about the methods used to generate it.

Decagon Devices, Inc.
2365 NE Hopkins Ct.
Pullman, WA 99163 USA
support@decagon.com
www.decagon.com