Complete Moisture Analysis

The importance of water in determining product safety and stability has long been recognized. The ancient natural preserving practices of salting, sugaring, brining, and dehydrating limit the growth of spoilage organisms by reducing the amount of available water. Traditionally, discussions on controlling the water in products have focused on moisture content or the total amount of water in a system. Moisture content provides valuable information about product quality, but it is only one part of a complete moisture analysis. Water activity is another important moisture measurement that provides essential information about the energy or availability of water in a product. Water activity and moisture content are both needed for a complete moisture analysis.

Why Measure Moisture Content?

Moisture content is the total amount of water in a product and is determined using many different techniques such as Karl Fischer, loss on drying, microwave, and NIR just to name a few. It is a common measurement in most labs and is particularly helpful in characterizing product quality. For example, moisture content provides information about nutritional labeling, concentration of solids, product texture, and product weight.

What is Water Activity?

Though not scientifically correct, it may help to picture water activity as the amount of available water in a system. It is not determined by how much water is present in a product, but is a comparison of how much the water in the product resembles and behaves like pure water. Water activity values represent a scale that ranges from 0 (bone dry) to 1.0 (pure water). As water activity decreases, the water in a product decreases in energy, is less available, and behaves less and less like pure water. For example, water in a product that has a water activity of 0.80 has enough energy to support mold growth while the water in a product with a water activity less than 0.60 cannot support the growth of any microorganism. Water also becomes more mobile as water activity increases, which influences molecular mobility as well as chemical and enzymatic reaction rates.

More scientifically, water activity represents the energy status of the water in the system and is equal to the relative humidity of the air in equilibrium with a sample in a sealed chamber. It is defined as the vapor pressure of water (p) over a sample divided by the vapor pressure of pure water (p_o) at a given temperature.

Why Measure Water Activity?

Water activity is the best index for microbial growth. A product may contain a relatively large percentage of moisture, but if the water is chemically "bound" with the addition of humectants or solutes, such as salts, sugars, or polyols, the water is biologically unusable for the microbial growth processes. The water activity concept has served microbiologists and food technologists for decades and is the most commonly used criterion for food safety and quality. Microorganisms have a limiting a_w below which they cannot grow.

Since water activity describes the thermodynamic energy status of the water within a system, there is a close relationship between water activity and the physical stability and shelf life of products. Differences in water activity levels between components or a component and the environmental humidity is a driving force for moisture migration. Knowledge of whether water will absorb or desorb from a particular component is essential to prevent degradation, especially if one of the substances is moisture sensitive. For example, if equal amounts of component 1 at 2% and component 2 at 10% moisture content are to be blended together, will there be moisture exchange between the components? The final moisture content of the blended material would be 6%, but did any moisture exchange between component 1 and 2? The answer depends on the water activities of the two components. If the water activities of the two components are the same, then no moisture will exchange between the two components.

Likewise, two ingredients at the same moisture content may not be compatible when mixed together. If two materials of differing water activities but the same water content are mixed together, the water will adjust between the materials until an equilibrium water activity is obtained. Thus, for a multi-component product, to prevent moisture migration, one should match the water activity of the two components. If one component is at a higher water activity than the other, water will migrate from

high water activity to low water activity. This migration could lead to undesirable changes in the quality of both components. Therefore, water activity provides useful information for formulation design, manufacturing conditions, and packaging requirements.

Relationship Between Water Content and Water Activity.

The relationship between water content and water activity is complex. An increase in water activity is usually accompanied by an increase in the water content, but in a nonlinear fashion. This relationship between water activity and moisture content at a given temperature is called the moisture sorption isotherm. For most foods, the isotherm is sigmoidal in shape, although foods that contain large amounts of sugar or small soluble molecules have a J-type isotherm curve shape. Many different equations are utilized to characterize a product's isotherm relationship. For small water activity ranges, linear regression can describe an isotherm relationship, but it rarely works for the entire water activity range. More complex equations are used to characterize the isotherm for the entire water activity range. The most common equations are the Guggenheim-Anderson-de Boer (GAB) and Brunauer-Emmett-Teller (BET) equations. Like linear regression, these equations are adjusted to find coefficients that do the best job of explaining the isotherm relationship. Data analysis software programs are used to determine these coefficients, which then can be used to predict the moisture content at any water level or vice versa.

Why Measure both Water Activity and Moisture Content?

While moisture content and water activity measurements individually provide necessary information, they are most effective when used together as a complete moisture analysis. For example, the moisture content associated with a water activity value may not be the same if a product adsorps water (starting from the dry state) or desorps (starting from the wet state) water. This phenomenon of different a_w vs. moisture values for adsorption and desorption is called moisture sorption hysteresis and is exhibited by many foods. This information is critical to anyone drying or wetting a product. Both moisture content and water activity are needed to determine if a product exhibits hysterisis.

A complete moisture analysis can also assist in optimizing formulations. Through formulation adjustments, it is possible to change the moisture content of a product at a given water activity. By comparing the moisture contents of the different formulations, it is possible to choose the formulation that has a higher moisture content, but still maintains a safe water activity level. In this example, moisture content provides information about concentration and moistness while water activity provides information about safety, quality, and shelf life. The result is a moister product that is still shelf stable. In addition, this product would weigh more with no additional work or energy costs. A complete moisture analysis can result in higher revenues at lower costs, all for selling water.

A Complete Moisture Analysis by a Single Instrument

Currently, moisture content and water activity are measured with different instrumentation. It is possible to determine moisture content based on water activity with high accuracy and speed through the moisture sorption isotherm. The process would require performing an isotherm for each product, then transferring the isotherm equation coefficients (eg. GAB, BET, Linear, etc.) for the product to a software program that would then use the equation coefficients and water activity values, as measured by a water activity instrument, to determine moisture content. This would allow a water activity instrument to become a complete moisture analyzer by providing both moisture content and water activity measurements. If you are interested in additional information about performing complete moisture analyses with one instrument, contact Decagon Devices.

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