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COMPLETE MOISTURE ANALYSIS - EXPLAINING THE ROLES PLAYED BY WATER ACTIVITY, MOISTURE CONTENT AND MOISTURE SORPTION ISOTHERMS

In food, pharmaceutical and cosmetics products, water plays a vital role. In food, for example, both water activity and moisture can have a dramatic impact on microbial activity (and hence safety), texture, mouth feel, taste, aroma, colour, shelf life, packaging design and manufacturing cost. However, the implications of both water activity and moisture content are often misunderstood, and the relationship between the two is sometimes not appreciated. This present article therefore seeks to explain water activity, moisture content and how the two relate to each other. It also discusses moisture sorption isotherms and how these can be used to predict behaviour.

Water activity (a_w) is a measure of how much water is free from physical and chemical bonds and is therefore available for migration, chemical reaction, use by microorganisms (moulds and bacteria, for example), or other activity. The correct definition of water activity is "a measure of the energy status of the water in a system" (in the past it was defined as "the amount of 'free' or 'available' water in a product as opposed to 'bound' water"). When considered in terms of the vapour pressure of water, water activity can be written as:

$$a_w = \frac{\text{Vapour pressure of water above sample at a given temperature}}{\text{Vapour pressure of pure water at the same temperature}}$$

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At the extremes, a sample with water activity of 0 is completely dry, while pure water has a water activity of 1.0. An alternative term is equilibrium relative humidity (ERH), which is expressed as a percentage, and a_w = ERH / 100.

Various models have been developed for predicting water activity (such as the Norrish Equation, Gover Model and Ross Equation) and computer programs are available for performing the necessary calculations.

Moisture content is easier to define, it being a quantitative measure of the amount of water. It is also easy to measure empirically by weighing the product before and after drying. Unlike water activity (which is a qualitative measure, independent of the amount of material in the sample), moisture content is a quantitative measure of the amount of water, and is therefore related to the amount of material in the sample - unless it is normalised and expressed as a percentage.

By taking a series of measurements, it is possible to plot a graph of the relationship between water activity and moisture content (as a percentage) at a specific temperature. This curve is known as an isotherm. Furthermore, water activity is temperature-dependent, so a family of isotherms can be created by collecting data for water activity and moisture content over a range of different temperatures. This can help to characterise a product and provide valuable insight when developing both the product and its packaging.

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To illustrate the difference between water activity and moisture content and to show how a family of moisture sorption isotherms might be used, consider a cheese-and-cracker sandwich. The cheese and the cracker will have levels of water activity and moisture content that are significantly different, but what will happen when the cheese and cracker are put together in a sandwich? Will the cracker absorb moisture from the cheese and lose its crunchy texture? The answer depends not on the moisture content but the water activity, by definition, moisture will migrate from the component with the higher water activity to that with the lower water activity, and the rate of migration will depend on the difference between the water activities of the two components.

A current user of moisture analysis instrumentation is the USA's Oak State Products, which makes cookies. Lots of them. In fact, Oak State has made, is making, or will make cookies for nearly every major cookie label. They make what the customer wants, and that starts with formulation in David Busken's lab.

Mr Busken is Manager of Research and Development at Oak State Products: 'Customers come to us with a concept, and we grow or refine that concept,' he says. 'They tell us what they want – longer shelf life, a particular protein or fiber content – and we do the formulation.' Figuring out how to make what the customer wants involves working with water activity meters.

Products made to be stocked on grocery store shelves need a shelf life of six months and that can get tricky with a soft cookie. 'Water activity is critical in soft cookies,' he says. 'There's been lots of R&D on how to keep cookies softer longer. We need to put moisture into the product and hold it there without making the water activity too high. You have to get the moisture in there, but if you go too high, you get mould.'

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David Busken says he will typically ‘work up a formula, make it up in the lab, bake it off, look at the water activity, then hold it and see now it ages.’ Some ingredients make formulation tougher. Fibres, for example, are ‘notorious. Because they suck up a lot of water. You put enough water in to get the right viscosity of the dough, and boom! The water activity is through the roof.’ Then with soft cookies, ‘the bake is critical. You can bake them enough to set up, but only water activity will tell you if you’ve baked it out enough. If the water activity is still too high, you’re going to have to do something about it.”

Water activity measurements are not just critical in the lab. Nearly all of Oak State’s customers demand water activity data, and most products must meet water activity specifications. ‘You can’t run without water activity,’ says David Busken. ‘If all the water activity instruments broke down, some lines could still run, but most would be shut down. You have to know where you’re at on water activity before you say “We’re good to go.”

Measuring water activity used to be a slow, laborious process, and the creation of moisture sorption isotherms even more so. Today there are cost-effective handheld and benchtop instruments that are suitable for both product development and quality assurance applications.

Labcell is the sole UK distributor for the Pawkit and AquaLab water activity instruments, and the VSA Isotherm Generator. For more information telephone +44 (0)1420 568150, email mail@labcell.com or visit Labcell's website at www.labcell.com.